Biological Evaluation of Kentucky's Water Quality Criterion for Selenium

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Revised Final Biological Evaluation of Revisions to Kentucky's Water Quality Standards for Selenium

I. Executive Summary

The focus of this biological evaluation is the effects which may occur to proposed, threatened and endangered species as a result of the Environmental Protection Agency (EPA) approval of water quality standards (WQS) under the Clean Water Act (CWA) for selenium adopted by the Commonwealth of Kentucky. The specific focus of this evaluation is 1) EPA approval of Kentucky's adoption of a whole body fish tissue criterion, and 2) possible EPA approval of a criterion structure where fish tissue criterion elements have primacy over water column criterion elements.

It is apparent from the EPA's research that the most significant threats to all the proposed, threatened, and endangered species in Kentucky are habitat loss and degradation associated with various kinds of human activities, such as development, impoundments, stream channelization, siltation caused by poor land use practices, logging, and oil, gas and mineral development. Selenium at levels allowed under Kentucky's whole body fish tissue criterion is not a major threat to the listed species. This biological evaluation provides the EPA's analysis of the potential effects of the EPA's action on threatened and endangered species and designated critical habitat by the approval of specific aspects of Kentucky's water quality standards. The EPA has found that the approved chronic aquatic life whole body fish tissue criterion for selenium will generally be beneficial to listed species and these provisions are not likely to lead to adverse effects. The EPA has also found that it is more accurate to rely on measures of selenium in fish tissue than measures of selenium in the water column to determine potential effects and protective levels for aquatic life in general, and also for proposed, threatened, and endangered species.

II. Description of Federal Action

Under Section 303(c) of the Clean Water Act (CWA) and 40 CFR § 131, States and authorized tribes have primary responsibility to develop and adopt water quality standards (WQS) to protect their waters. As required by Section 303(c) of the CWA and 40 CFR § 131, the EPA reviews new and revised WQS that have been adopted by States and authorized tribes. State and Tribal WQS are not considered effective under the CWA until approved by the EPA.

The Federal action being evaluated is the EPA approval of the revised selenium criterion as it relates to the protection of aquatic life use as set forth in the Kentucky Administrative Regulations Title 401 Chapter 10. The specific focus of this evaluation is 1) EPA approval of Kentucky's adoption of a whole body fish tissue criterion, and 2) possible EPA approval of a criterion structure where fish tissue criterion elements have primacy over water column criterion elements. EPA took the first action in November 2013 and anticipates the potential for the second action in the future. This evaluation does not address any EPA action, taken in the past or contemplated for the future, to approve Kentucky's removal of a specific water column criterion element or adoption of a specific egg-ovary fish tissue criterion element.

Section 303(c)(3) of the CWA states in part:

> If the Administrator, within sixty days after the date of submission of the revised or new standard, determines that such standard meets the requirements of this Act, such standard shall thereafter be the water quality standard for the applicable waters of the State.

A. History of Consultation on CWA Activities

Section 7(a)(2) of the Endangered Species Act (ESA) requires the EPA, in consultation with the U.S. Fish and Wildlife Service (USFWS) and/or the National Marine Fisheries Service (NMFS), to ensure that any action authorized by the agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat for such species. As provided in the Memorandum of Agreement between the EPA, the USFWS, and NMFS regarding enhanced coordination of CWA and ESA obligations, the EPA uses a biological evaluation to analyze whether a new or revised water quality standard may affect Federally-listed species or designated critical habitat. This Biological Evaluation (BE) has been prepared to determine whether EPA's approval of specifc aspects of Kentucky surface water quality standards may affect federally listed endangered or threatened species or designated critical habitat of such species. If the EPA determines that approval may affect listed species or critical habitat but is not likely to adversely affect listed species or habitat, then formal consultation with the USFWS is not required if the EPA obtains concurrence on the "not likely to adversely affect" (NLAA) finding from the USFWS.

Informal consultation began on August 30, 2012 with an email from the EPA to the USFWS requesting review and comment on Kentucky's proposed revisions to their regulations and to provide the EPA with the most current species list.[1] On June 25, 2013, EPA sent the USFWS a first draft of the BE addressing the WQS revisions adopted by Kentucky and a revised BE on July 8, 2013. On November 15, 2013, the EPA sent the revised final BE and transmittal letter to the Kentucky Ecological Services Field Office in Frankfort, Kentucky. On December 27, 2013 the Kentucky Ecological Services Field Office sent a non-concur letter to the EPA.

In conversations between the EPA and the USFWS since the December 27, 2013 letter, the USFWS noted the following concerns with the BE: the accuracy of the threatened and endangered (T&E) species list that EPA used in its BE, the possibility of indirect effects on the Kentucky cave shrimp, the lack of determinations for proposed species, and the lack of an explanation for the species analysis and the endpoint for the selenium criterion. The EPA has addressed theseconcerns with respect to WQS approval actions related to nutrients in the April 29, 2015 BE and will address the selenium analysis in this BE.

The USFWS and the EPA held a conference call discussion on February 13, 2014 to confer on the issues in the "non-concur" letter. The EPA agreed to revise the BE by adding the species in the updated list, consider the cave shrimp with information the USFWS would provide, and

[1] Endangered Species Act Consultation Handbook. Procedures for conducting Section 7 consultations and conferences USFWS. NMFS. March 1998 p xv, p 3-6, 3-7

provide direct, indirect and cumulative impact analyses based on example BE(s) that the USFWS would provide.

On May 6, 2014 the EPA sent a draft response letter and the draft revised BE based on the previous conversations the EPA had with the USFWS. On July 11, 2014 the USFWS received another revised draft BE and revised draft response letter. The EPA requested a face-to-face meeting with the USFWS at their Field Office in Frankfort, Kentucky on August 5, 2014 to discuss the draft documents and work toward agreement on the BE. At the meeting, the EPA agreed to initiate formal consultation on the aquatic life chronic criterion for selenium.

A conference call was held on November 19, 2014 between the EPA and the USFWS to discuss the technical analysis requirements for the BE in formal consultation which would address the USFWS's issues and concerns on the Kentucky selenium criterion. To aid in this effort the EPA requested the following from the USFWS:

- the identification of the T&E listed species in Kentucky that are aquatic-dependent
- an example of a step-by-step effects analysis that considers a specific life history or habitat of a specific species
- citations of reports/studies that should be considered that were not listed in the USFWS's comment letter to EPA
- the Kentucky cave shrimp information as stated above, and
- the example BE(s) as stated above

A December 11, 2014 letter from the USFWS identified the species that the USFWS believes need to be considered in the BE (with the addition of the northern long-eared bat), initial rationale on why adverse effects may occur (without citations), identification of the T&E listed species which are aquatic dependent, identification of critical habitats by species, identification of species that the EPA would not need to include in the BE, and identification of species where a not likely to adversely affect determination may be appropriate. On January 14, 2015, the EPA received a CD from the USFWS containing a compilation of data for the EPA's use in development of the BE.

B. Overview of Water Quality Standards

A water quality standard defines the water quality goals for a waterbody by designating the use or uses of the water, by setting criteria necessary to protect the uses, and by preventing or limiting degradation of water quality through antidegradation provisions. The CWA provides the statutory basis for the water quality standards program and defines broad water quality goals.

Section 101(a)(2) of the CWA sets out a national goal that wherever attainable, waters achieve a level of quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water ("fishable/swimmable").

Section 303(c) of the CWA requires that all states adopt water quality standards and that the EPA review and approve these standards. In addition to adopting water quality standards, states are required to review those standards every three years and to then revise the standards, as necessary. This public process, commonly referred to as the triennial review, allows for new technical and scientific data to be considered in order to update the standards. The regulatory requirements governing water quality standards are established at 40 Code of Federal Regulations (CFR) Part 131.

The purpose of the CWA, 33 U.S.C.S. § 1251(a), is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Consistent with the CWA, as part of their water quality standards, states must designate the uses for which their waters are to be protected, such as fishing and swimming, and identify water quality criteria to protect the uses for pollutants that could reasonably be expected to interfere with the designated uses. In addition, states' water quality standards must include an antidegradation policy and implementation procedures that are consistent with the EPA's policy to protect existing uses, high quality waters, and water quality in waters identified by the state as outstanding national resource waters. Id. § 1313(c)(2)(A) (Supp. 1993); 40 C.F.R. § 131. Under section 303 of the CWA, states must submit new and revised water quality standards to the EPA for review and approval. When a state submits its water quality standards to EPA for review, the standards must include: (1) the designated uses for each body of water; (2) what methods were used and analyses conducted to support the revisions to state water quality standards; (3) water quality criteria, which protect the designated uses for each water body and which may be expressed as either a narrative standard or a numeric concentration level; and (4) an antidegradation policy to protect existing uses of bodies of water and high-quality waters. 40 C.F.R. §§ 131.3(i), 131.3, 131.6, 2131.12.

C. Description of Specific Kentucky Provisions Approved by EPA

The Kentucky Cabinet for Energy and Environment, Department for Environmental Protection, adopted and the Division of Water submitted, new and revised water quality standards to the EPA Region 4 on May 23, 2013. The EPA approved the following criterion on November 15, 2013.

401 KAR 10:031 Section 6(1) Table 1.[2]

Pollutant	CAS Number	Water Quality Criteria µg/L
		Chronic Warm Water Aquatic Habitat:
Selenium	7782492	<u>8.6[10, 11]</u> [~~5.0~~]

[10]This value is the concentration in µ/g (dry weight) of whole fish tissue.
[11]A concentration of five and zero tenths (5.0) µg/L or greater selenium in the water column shall trigger further sampling and analysis of whole-body fish tissue or alternately of fish egg/ovary tissue.

The cabinet updated its chronic warm water aquatic habitat criterion for selenium by replacing the 5.0 µg/L water column number with a fish tissue criterion. The chronic water quality criterion for warm water aquatic habitat for selenium (derived based on species native or naturalized to Kentucky waters, or species that serve as appropriate surrogates to native fish

[2] Pursuant to 401 KAR 10:031 Section 4(j)(5), the values set out in Table 1 represent the allowable instream concentrations for specific pollutants to protect warm water aquatic habitat. Pursuant to 401 KAR 10:031 Section 4(1), warm water aquatic habitat includes fowl, animal wildlife, arboreous growth, agricultural, and industrial uses.

species) is 8.6 µg/g dry weight of whole fish tissue. The approach Kentucky used to derive this number is similar to the conventional Sensitivity Distribution Approach used by the EPA (Stephan et al. 1985). The criterion provides the concentration of selenium in fish tissue determined to be protective of the designated use. If a species-composite fish tissue has a selenium concentration that exceeds this value, the waterbody is considered to be in non-attainment of the water quality standard.

Kentucky has interpreted and implemented their selenium WQS for aquatic life protection such that fish tissue criterion elements have primacy over measures of selenium concentrations in the water column. Within their adopted regulations, Kentucky refers to the value of 5.0 µg/L in the water column as a "trigger" for further sampling and and analysis of whole-body fish tissue, with the implicit goal to evaluate attainment of WQS using fish tissue data. In addition, Kentucky issued a general permit with a provision that applies a 5.0 µg/L effluent concentration to determine compliance in cases where adequate representative fish tissue samples cannot be obtained. In its 2014 draft selenium criterion document, EPA posited that fish tissue criterion elements should override water column criterion elements when both fish tissue and water concentrations are measured and that states and tribes should express a multi-part criterion in a manner that explicitly affirms the primacy of fish tissue elements over water column elements. EPA further anticipates the possibility that Kentucky may explicitly clarify the relationship between any fish tissue criteria for selenium and any water column criteria for selenium in their WQS. Should EPA be in the position of approving such a criterion construction, the Agency believes it would be scientifically defensible and protective, and be not likely to adversely affect proposed, threatened, or listed species in the Commonwealth of Kentucky.

Kentucky's derivation of criteria is described in detail in *Update to Kentucky Water Quality Standards for Protection of Aquatic Life: Acute Selenium Criterion and Tissue-Based Selenium Chronic Criteria*, dated April 3, 2013. Kentucky considered and evaluated the studies the EPA used in its draft selenium criteria document (USEPA. 2004) and additional data that became available since that time, including studies that the EPA listed in 2008 as meriting consideration. In the derivation of its fish tissue criterion, the Kentucky Division of Water (KDOW) considered the available toxicity data for 10 species that either reside in the Commonwealth or are surrogates for related resident species. The species considered were bluegill, largemouth bass, brook trout, brown trout, rainbow trout, northern pike, white sucker, white sturgeon, western mosquitofish, and fathead minnow. Overall, Kentucky's interpretations of these studies do not differ significantly from the interpretations either of the 2004 EPA Draft Aquatic Life Water Quality Criterion for Selenium or of the 2009-2010 expert panel of the Society of Environmental Toxicology and Chemistry (Ecological assessment of selenium in the aquatic environment: Summary of a SETAC Pellston Workshop, Chapman et al.). The conversions between egg/ovary and whole-body concentrations are likewise based on data that the EPA believes are sound. Furthermore, the whole-body criterion was derived using species sensitivity distribution concepts similar to the EPA's 1985 guidance approach (Stephan et al. 1985). In brief, the criterion predicts a 10% effect (larval effects in fish) on the theoretical 5th percentile genus (more senstitive than 95% of genera) based on all available and relevant toxicology. Per EPA's 1985 Guidelines, either the EC_{20} (concentration affecting 20% of the tested animals) or the EC_{10} (concentration affecting 10% of the tested animals) should be used as the endpoint for chronic studies. EC_{20}s have historically been used in the derivation of EPA criteria applicable to the water medium.

While water concentrations may vary rapidly over time, tissue concentrations of bioaccumulative chemicals are expected to vary gradually. For concentrations of selenium in fish tissue the lower level of effect of EC_{10} (10 percent effect level) was selected to attain sufficient protection due to the bioaccumulative nature of selenium. Further, the EC_{10} was also preferred over the No Observed Effect Level (NOEC) or Lowest Observed Effect Level (LOEC) as these latter measures of effect are highly influenced by study design, specifically the concentrations tested, the number of concentrations tested, the number of replicates for each concentration, and the number of organisms in each replicate. Importantly, as noted by Campbell (2011), EC_{10}s and NOECs are generally of similar magnitude, but EC_{10}s have the advantage of being more reproducible than NOECs since EC10s are determined statistically, whereas NOECs are a function of the particular study design (Van der Hoeven et al. 1997; Warne and van Dam 2008). For these reasons, the EPA believes that criterion values that result from applying this approach protect aquatic life against the harmful effects of selenium and are scientifically defensible and expected to be protective of the designated use.

The scientific defensibility of the criterion stems, in part, from the use of fish data for species found in Kentucky waters that could be expected to accumulate selenium. In addition, the genera of fish that were in the analysis fulfilled the minimum data requirements as outlined in EPA's 1985 Guidelines. Because the field observations of contaminated sites have found effects on fish in the absence of changes in invertebrate assemblages, scientific studies on invertebrates on chronic toxicity of dietary selenium have been very limited. The few dietary chronic toxicity studies that are available for invertebrate species indicate that they are among the more selenium-tolerant aquatic taxa. Because the 5^{th} percentile calculation methods for the criterion per the Guidelines use actual numeric values of only the four most sensitive genera (fish) in the selenium dataset, it is only necessary to know that the more tolerant genera have chronic effect levels that are greater than those of the lowest four genera. Therefore, fish data were sufficient and relevant to support the criterion, and the derivation of the criterion was consistent with the EPA's own approach as outlined in EPA's 1985 Guidelines.

The development of this criterion is consistent with the EPA's Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (1985 Guidelines). Kentucky's revised chronic water quality criterion for warm water aquatic habitat for selenium is scientifically defensible and are protective of the designated use of warm water aquatic habitat in the Commonwealth's water bodies.

III. Scope of Analysis

The EPA obtained a current ESA species list (55 species) for the state of Kentucky from the U.S. Fish & Wildlife Service Kentucky Ecological Services Field Station in a letter dated December 11, 2014. This list is the account governing the species to be considered in this consultation.

Pursuant to conversations with the USFWS the following threatened and endangered species will be considered in this evaluation. This list contains all species currently listed and proposed for listing under the ESA, which are known or suspected to occur in the Commonwealth of Kentucky.

A. Species of Interest for ESA Consultation

A.1 Mammals

Gray bat	*Myotis grisescens*
Indiana bat	*Myotis sodalis*
Northern long-eared bat	*Myotis septentrionalis*
Virginia big-eared bat	*Corynorhinus townsendii virginianus*

A.2 Birds

Red knot	*Calidris canutus rufa*
Piping plover	*Charadrius melodus*
Whooping crane	*Grus americana*
Interior Least tern	*Sterna antillarum*

A.3 Fish

Diamond darter	*Crystallaria cincotta*
Relict darter	*Etheostoma chienense*
Duskytail darter	*Etheostoma percnurum*
Cumberland darter	*Etheostoma susanae*
Palezone shiner	*Notropis albizonatus*
Blackside dace	*Phoxinus cumberlandensis*
Pallid sturgeon	*Scaphirhynchus albus*
Shovelnose sturgeon	*Scaphirhynchus platorynchus*

A.4 Crustaceans

Kentucky cave shrimp	*Palaemonias ganteri*

A.5 Freshwater Mussels

Cumberland elktoe	*Alasmidonta atropurpurea*
Spectaclecase	*Cumberlandia monodonta*
Fanshell	*Cyprogenia stegaria*
Dromedary pearlymussel	*Dromus dromas*
Cumberlandian combshell	*Epioblasma brevidens*
Oyster mussel	*Epioblasma capsaeformis*
Tan riffleshell	*Epioblasma florentina walkeri*
Catspaw	*Epioblasma obliquata obliquata*
Northern riffleshell	*Epioblasma torulosa rangiana*
Snuffbox	*Epioblasma triquetra*
Cracking pearlymussel	*Hemistena lata*
Pink mucket	*Lampsilis abrupta*
Scaleshell	*Leptodea leptodon*

Ring pink	*Obovaria retusa*
Littlewing pearlymussel	*Pegias fabula*
White wartyback	*Plethobasus cicatricosus*
Orangefoot pimpleback	*Plethobasus cooperianus*
Sheepnose	*Plethobasus cyphyus*
Clubshell	*Pleurobema clava*
Rough pigtoe	*Pleurobema plenum*
Slabside pearlymussel	*Pleuronaia dolabelloides*
Fat pocketbook	*Potamilus capax*
Fluted kidneyshell	*Ptychobranchus subtentum*
Rabbitsfoot	*Quadrula c. cylindrica*
Winged mapleleaf	*Quadrula fragosa*
Cumberland bean	*Villosa trabilis*

All of these species reside all or part of their lives or depend on forage species in the freshwaters of Kentucky and therefore could be affected by surface water quality standards.

B. Discussion Species

The listed and proposed species that will not be the focus of this consultation are the American burying beetle which is not an aquatic or aquatic-dependent species and the listed plants, none of which are considered aquatic or aquatic-dependent species. These species generally occur in uplands, riparian areas, or wetland edges. It was determined that these species (or their critical habitat) would not be directly impacted by changes to the Kentucky criterion and thus the approval of the changes in this criterion would not likely have an adverse effect on these species (USFWS December 11, 2014 letter). The following is a list of these species.

B.1 Insects

American burying beetle (possibly extirpated)	*Nicrophorus americanus*

B.2 Plants

Price’s potato-bean	*Apios priceana*
Braun’s rockcress (CH)	*Arabis perstellata*
Cumberland sandwort	*Arenaria cumberlandensis*
Cumberland rosemary	*Conradina verticillata*
Kentucky glade cress	*Leavenworthia exigua* var. *laciniata*
Short’s bladderpod	*Physaria globosa*
American chaffseed	*Schwalbea americana*
Virginia spiraea	*Spiraea virginiana*
White-haired goldenrod	*Solidago albopilosa*
Short’s goldenrod	*Solidago shortii*
Running buffalo clover	*Trifolium stoloniferum*

IV. Description of the Specific Geographic Area that May Be Affected by the Action:

The Kentucky Energy and Environment Cabinet, Department for Environmental Protection, Division of Water has the authority to develop surface water quality standards that apply to waters of the state. The action area of this consultation consists of all surface waters of the United States within the jurisdiction of the Commonwealth of Kentucky for which the aquatic life criterion for selenium has been approved. The area evaluated for action is the applicable waters of the Commonwealth of Kentucky which are defined at 401 KAR 10:001(80) as:

> *surface waters means those waters having well-defined banks and beds, either constantly or intermittently flowing; lakes and impounded waters; marshes and wetlands; and any subterranean waters flowing in well-defined channels and having a demonstrable hydrologic connection with the surface.*

V. Effects of the Action

A. Overview

The ESA Section 7 implementing regulations (50 CFR 402.02) define "effects of the action" as:

> "The direct and indirect effects of an action on the species or critical habitat together with the effects of other activities interrelated or interdependent with that action, that will be added to the environmental baseline. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early Section 7 consultation, and impact of State or private actions which are contemporaneous with the consultation in process. Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur."

B. Direct Effects

For this EPA action, there are no direct effects to ESA-listed species or designated critical habitat. Approval of Kentucky's water quality fish tissue criterion for whole body does not cause direct or immediate effects on species or critical habitat. Any effects that may occur would be indirect effects (see below).

C. Indirect Effects

Approving water quality standards may have indirect effects to listed species when CWA programs are applied. These effects are indirect because they are likely to occur later in time when the programs are implemented. Examples of CWA programs that may lead to indirect effects include TMDL management plan implementation, issuance of KPDES permits, CWA 401 certifications of federally licensed projects, and implementation of non-point source management plans designed to meet the water quality standards over time. These programs are intended to control inputs of point-source and nonpoint-source pollution to waterbodies such that the water quality standards are met in the receiving waters and aquatic life is protected.

Note: The discussion below describes the various CWA programs related to implementation actions to attain water quality standards. Effects to listed species may occur when on-the-ground implementation occurs. However, EPA is not assessing the adequacy of these programs to attain standards because EPA's action does not address approval of these various programs. EPA's action is approval of the standards. Therefore, the effect analysis on pages 62 – 83 examines the effects to listed species and critical habitat of the standards themselves, assuming the standards are attained. The discussion below is intended to provide context of how EPA's approval of standards relates to real on-the-ground actions that may affect listed species.

Kentucky's surface water quality standards consist of three primary components: 1) designated uses (e.g., warm and cold water aquatic habitat; recreation; and domestic water supply) that are assigned to the waters; 2) numeric and narrative criteria that are designed to protect the specified designated uses; and 3) a water quality antidegradation program that provides special protection for existing uses and high quality waters.

The water quality standards establish the foundation for the state's water pollution control programs. Under state and federal laws and regulations human sources of pollution must not cause or contribute to an exceedence of the water quality standards. As such, regulated activities must be designed and implemented to achieve the water quality standards. While the water quality standards of the Commonwealth of Kentucky apply broadly to all categories and sources of pollution, there are jurisdictional and practical limitations that affect how well certain sources of pollution are brought into compliance. The following discussion is intended to provide a general overview on how the water quality standards may be applied to protect water quality in the Commonwealth of Kentucky.

VI. Overview of WQS Implementation in the Point Source Discharge Program

Point sources are "any discernable, confined and discrete conveyance . . . from which pollutants are or may be discharged" (such as from a pipe, ditch, or channel). See 33 U.S.C. 1362(14). Formal permit programs are established under state and federal laws and regulations for point source discharges. These regulations include the requirement that permits be established to achieve the applicable water quality standards. See 40 C.F.R. 122.44(d)(1).

Water quality criteria that are part of approved water quality standards are the basis for establishing effluent limits in KPDES permits where there is reasonable potential that a point source discharge will cause or contribute to its violation. Current dischargers would generally not be expected to increase their selenium loading based on a revised WQS (a discharger that is meeting a current limit for selenium would be expected to continue to at least meet that current limit), but may be subject to a more stringent limit. However, new or expanding dischargers may increase loadings to the environment, but not to exceed the ambient level specified in the revised WQS, and generally applying conservative assumptions such that a margin of safety is provided.

A. KPDES Permits for Municipal and Industrial Dischargers

Municipal wastewater treatment facilities and industrial facilities that discharge wastewater are regulated under KPDES permits. Kentucky identifies point sources of wastewater and requires that those facilities obtain and comply with a wastewater discharge permit. These permits set limits for the amount of pollutants that may be discharged to ambient waters. Limitations are established for wastewater wherever: a) the EPA or the Commonwealth has established minimum technology-based controls for a wastewater pollutant for the type of activity being regulated, or b) a reasonable potential exists for the wastewater discharge to exceed a water quality standard. Permit conditions generally include effluent limits, periodic monitoring to ensure that the effluent limits are being met, compliance conditions requiring improvements in operation or special studies, special operating conditions, and other administrative requirements such as prompt reporting of any spills. KPDES permits are on a five year renewal cycle that allows new water quality standards to be considered and incorporated in existing permits. Permits can be administratively extended under the Administrative Procedures Act (1984), but this is not the EPA's preferred mode of action.

B. KPDES General Permits

General permits are issued by Kentucky to cover categories of discharges within a geographic area. See 40 C.F.R. 122.2. General permits usually cover numerous discharge sources that share common characteristics. General permits cover a wide range of potential dischargers (e.g. municipal stormwater, industrial stormwater, construction stormwater, and coal mining). General permits normally include best management practices, or in some cases discharge benchmarks, designed to meet standards.

VII. Environmental Baseline for Selenium

Natural selenium introduction occurs via water percolation through seleniferous soils (Dobbs et al. 1996). Typical background concentrations of selenium have been estimated at 0.25 µg/L (Wilber 1980), 0.1 to 0.3 µg/L (Lemly 1985), 0.2 µg/L (Lillebo et al 1988), and 0.1 to 0.4 µg/L (average <0.2, Maier and Knight 1994). Discharge of subsurface agricultural drainage water to surface waters is a major pathway for the mass-loading of selenium into aquatic ecosystems.

Of all the priority and non-priority pollutants, selenium has the narrowest range of what is beneficial for biota and what is detrimental. Aquatic and terrestrial organisms require 0.5 µg/g dry weight (dw) of selenium in their diet to sustain metabolic processes, whereas concentrations of selenium that are only an order of magnitude greater than the required level have been shown to be toxic to fish. Acute effects are observed after short exposure durations of typically 96 hours or less. Acute effects from the inorganic forms of selenium, selenite and selenate, require concentrations exceeding 300 µg/L, concentrations rarely reached in the environment. In contrast, toxic effects from long-term chronic exposure via diet and water can result in reduction of species in aquatic systems with aqueous concentrations less than 20 µg/L (Lemly 1985). As a result of the greater sensitivity to selenium from chronic exposures, water quality management practices over the last 10-15 years have focused on the control of chronic effects. Studies have shown that diet is the primary route of exposure that controls chronic toxicity to fish, the group considered to be the most sensitive to chronic selenium exposure (Coyle et al. 1993; Hamilton et al. 1990; Hermanutz et al. 1996).

VIII. Description of the Listed Species' Critical Habitat

A. Critical Habitats where EPA's Action will have no effect

A.1 Indiana bat

Critical habitat (CH) for the Indiana bat is found in Bat Cave in Carter County and Coach Cave in, Edmonson County. These areas were designated on September 24, 1976 (41 FR 41914-41916). The most significant range wide threats to the Indiana bat have been habitat loss/degradation, forest fragmentation, winter disturbance, and environmental contaminants. In addition to these threats, climate change and White-Nose Syndrome are increasingly being identified as significant threats to the future recovery of the Indiana bat and its congeners. Anthropogenic factors that may affect the continued existence of Indiana bats include numerous environmental contaminants (e.g., organophosphate and carbamate insecticides, oil spills, and PCBs), collisions with manmade objects (e.g., poorly constructed cave gates, vehicles, aircraft, communication towers, and wind turbines) and climate change (Indiana Bat 5-Year Review: Summary and Evaluation 2009).

The EPA's action will have no effect on designated CH for Indiana bats because the cave systems designated as CH for this species are not aquatic habitats and the proposed action is unlikely to result in any alteration of these CH areas that would result in the adverse modification of the CH (USFWS letter December 11, 2014).

A.2 Braun's rockcress

There are 14 units in Franklin County and 3 in Owen County (69 FR 31460 - 31496).

A.3 Kentucky glade cress

There are 6 units (18 subunits) in Bullitt and Jefferson counties (79 FR 25689 – 25707, May 6, 2014).

A.4 Short's bladderpod

There are 6 units in Clark, Franklin and Woodford counties (79 FR 50989 – 51039). August 26, 2014).

The EPA's action will have no effect on designated CH for Braun's rockcress, Kentucky glade cress or Short's bladderpod because the upland habitat areas designated as CH for these plant species are not aquatic habitats and the action is unlikely to result in any alteration of these CH areas that would result in the adverse modification of the CH (USFWS December 11, 2014 letter).

B. Critical Habitats where EPA's Action may have an Indirect Effect

B.1 Diamond darter

Critical habitat for the Diamond darter is found in the Green River in Green, Hart, and Edmonson Counties. The rule for designation of critical habitat became effective on September 23, 2013 (78 FR 52363 – 52387). In total, approximately 197.1 river kilometers (122.5 river miles) in Kanawha and Clay Counties, West Virginia, and Edmonson, Hart, and Green Counties, Kentucky, have been designated as critical habitat.

Habitat features essential to the diamond darter (*Crystallaria cincotta*)[3] are clean, stable substrates, good water quality, and healthy benthic invertebrate populations. The diamond darter has been found in moderate-to-large (fourth- to eighth-order) perennial warmwater streams with moderate to strong velocities (e.g., 32 cm/sec), and clean sand and gravel substrates. Riffle-pool complexes and glide habitats are also an important habitat for this species (78 FR 52364, August 22, 2013; Welsh et al. 2013). Riffle-pool transition areas are used for cover and shelter as well as for ambush foraging. Some studies suggest that *Crystallaria* travel upstream to reproduce, and free-floating young-of-the-year disperse downstream during spring high water to find a suitable habitat to grow and mature, suggesting that *Crystallaria* make long-distance movements in large rivers. Thus, variability in the substrate and available habitat conditions are important because darters may shift to different habitat types during different life stages to adapt to changing conditions (78 FR 52364, August 22, 2013). Feeding habits of the diamond darter in the wild are not known; however, based on studies of the crystal darter, adult diamond darters are benthic invertivores. Adult crystal darters eat midge and caddisfly larvae, and water mites; and juvenile and young eat immature stages of aquatic insects such as mayflies, craneflies, blackflies, caddisflies, and midges as well as zooplankton prey (78 FR 52364, August 22, 2013).

Critical habitats include primary constituent elements (PCEs) that exist for the diamond and Cumberland darters. PCEs for these species are almost identical except for stream order and requirements for cover (77 FR 63604, October 16, 2012; 78 FR 52364, August 22, 2013).

Crystallaria cincotta, Diamond Darter (78 FR 52364, August 22, 2013)

(1) Primary Constituent Element 1—A series of connected riffle-pool complexes with moderate velocities in moderate- to large-sized (fourth- to eighth-order), geomorphically stable streams within the Ohio River watershed.
(2) Primary Constituent Element 2—Stable, undisturbed sand and gravel stream substrates that are relatively free of and not embedded with silts and clays.
(3) Primary Constituent Element 3—An instream flow regime (magnitude, frequency, duration, and seasonality of discharge over time) that is relatively unimpeded by impoundment or diversions such that there is minimal departure from a natural hydrograph.
(4) Primary Constituent Element 4—Adequate water quality characterized by seasonally moderated temperatures, high dissolved oxygen levels, and moderate pH, and low levels

[3] Little information is available on the diamond darter. When information is limited, analyses by USFWS rely on information on the crystal darter (*Crystallaria asprella*).

of pollutants and siltation. Adequate water quality is defined as the quality necessary for normal behavior, growth, and viability of all life stages of the diamond darter.

(5) Primary Constituent Element 5—A prey base of other fish larvae and benthic invertebrates including midge, caddisfly, and mayfly larvae.

B.2 Cumberland darter

Critical habitat for the Cumberland darter is found in Bunches Creek, Calf Pen Fork, Capuchin Creek, Jellico Creek,Wolf Creek, and Youngs Creek in Whitley County; Barren Fork, Capuchin Creek, Cogur Fork, Elisha Branch, Indian Creek, Jellico Creek, Jenneys Branch, Kilburn Fork, Laurel Creek, Laurel Fork, and Rock Creek in McCreary County. The designation of these critical habitats became effective on October 16, 2012 (77 FR 63603-63668).

The Cumberland darter occurs in a small, reduced range in the Cumberland River drainage above Cumberland Falls in eastern Kentucky and adjacent Tennessee. Currently, the species is known from 15 localities in a total of 13 streams in Kentucky (McCreary and Whitley counties) and Tennessee (Campbell and Scott counties). All 15 extant occurrences are restricted to short stream reaches, with the majority believed to be restricted to less than 1.6 kilometers of stream. These occurrences are thought to form six population clusters (Bunches Creek, Indian Creek, Marsh Creek, Jellico Creek, Clear Fork, and Youngs Creek), which are geographically separated from one another by an average distance of 30.5 stream kilometers (USFWS 2011).

Habitat loss and modification represent significant threats to the Cumberland darter. This fish inhabits shallow water in low velocity shoals and backwater areas of moderate to low gradient stream reaches with stable sand or sandy-gravel substrata. It is not found in areas with cobble or boulder substrata. All specimens that have been collected in recent years have been found in less than 15 centimeters of water (Laudermilk and Cicerello 1998).

Etheostoma susanae, Cumberland Darter (77 FR 63604, October 16, 2012)

(1) Primary Constituent Element 1— Shallow pools and gently flowing runs of geomorphically stable, second- to fourth-order streams with connectivity between spawning, foraging, and resting sites to promote gene flow throughout the species' range.
(2) Primary Constituent Element 2—Stable bottom substrates composed of relatively silt-free sand and sand-covered bedrock, boulders, large cobble, woody debris, or other cover.
(3) Primary Constituent Element 3—An instream flow regime (magnitude, frequency, duration, and seasonality of discharge over time) sufficient to provide permanent surface flows, as measured during years with average rainfall, and to maintain benthic habitats utilized by the species.
(4) Primary Constituent Element 4—Adequate water quality characterized by moderate stream temperatures, acceptable dissolved oxygen concentrations, moderate pH, and low levels of pollutants. Adequate water quality is defined for the purpose of this rule as the quality necessary for normal behavior, growth, and viability of all life stages of the Cumberland darter.
(5) Primary Constituent Element 5—Prey base of aquatic macroinvertebrates, including midge larvae, mayfly nymphs, caddisfly larvae, and microcrustaceans.

Key PCE elements for both the diamond and Cumberland darters are geomorphically stable streams, stable stream bottom substrates, sufficient instream flow regime, adequate water quality, and habitats allowing for an adequate prey base. Adequate water quality is characterized by moderate stream temperatures, acceptable dissolved oxygen concentrations, moderate pH, and low levels of pollutants, and provides the quality necessary for normal behavior, growth, and viability of all life stages of both the diamond darter and the Cumberland darter (77 FR 63604, October 16, 2012; 78 FR 52364, August 22, 2013). Habitats must accommodate foraging, breeding, growth, and migration during various life stages. In addition, habitats should support the physical, chemical, and biological conditions necessary for the survival of their prey. Habitat features essential to these taxa include good water quality, clean and stable substrates (i.e., silt-free), and healthy benthic invertebrate populations (77 FR 63604, October 16, 2012; 78 FR 52364, August 22, 2013).

Habitat fragmentation increases the risk of genetic isolation, leaves reduced space for rearing and reproduction, and increases the likelihood of local extinctions, thus the connectivity of habitats is essential to the survival of these species (77 FR 63604, October 16, 2012). Siltation, impoundment, and coal mining are identified as the major threats. The most significant of these impacts is siltation (excess sediments suspended or deposited in a stream) caused by excessive releases of sediment from activities such as resource extraction (e.g., coal mining, silviculture, natural gas development), agriculture, road construction, and urban development (Waters 1995, pp. 2-3; Thomas 2007, p. 5, 77 FR 63604, October 6, 2012). Siltation contributes to turbidity of the water and has been shown to reduce photosynthesis in aquatic plants, suffocate aquatic insects, smother fish eggs, clog fish gills, and may fill in essential interstitial spaces (spaces between stream substrates) used by aquatic organisms for spawning and foraging; therefore, excessive siltation negatively impacts fish growth, physiology, behavior, reproduction, and survival (77 FR 63604, October 6, 2012).

The diamond darter and the Cumberland darter are known to be particularly susceptible to siltation (Bennett 2003; USFWS 2013c; 58 FR 25758, April 27, 1993; 77 FR 63604, October 16, 2012; 78 FR 52364, August 22, 2013).

The diamond darter has been extirpated from all of the Kentucky streams and is now known to occur only within the lower Elk River in West Virginia.

B.3 Kentucky cave shrimp

Critical habitat for the Kentucky cave shrimp is found in the Roaring River Passage, Mammoth Cave National Park. The designation of critical habitat became effective on October 12, 1983 (48 FR 46337 – 46342).

Critical habitat PCE requirements were not included with the *Federal Register* notice for this species and were, therefore, inferred from the text (45 FR 68975, October 17, 1980; 48 FR 46337, October 12, 1983). These habitat elements include streams in base-level cave passages with seasonally quiet pools, abundant quantities of organic matter, and coarse silt-to-very coarse-to-very fine sands (DeGrave and Rogers 2013). Other evidence suggests the species may be able to breed outside of the quiet pool habitat (48 FR 46337, October 12, 1983). The species is a collector-gatherer invertebrate that appears to feed primarily on detrital material from a variety of primarily allochthonous sources.

Increased siltation may cause a decline in the available food supply for Kentucky cave shrimp by limiting the available habitat for stream interstitial fauna. This fauna is a large and significant portion of the food web base in cave streams and is very habitat specific. According to KDOW (2006), nonpoint-source impacts on groundwater in Kentucky are caused primarily by agriculturally related nutrients and pesticides. Pollutants of concern include nitrates (from fertilizer application, manure storage and application, and animal feeding operations), pesticides and herbicides (U.S. Fish and Wildlife. 2007). Lock and Dam No. 6 is the most severe ecosystem management issue in Mammoth Cave National Park (Olson et al., 2013).

B.4 Cumberland elktoe

Critical habitat for the Cumberland elktoe is found in the Big South Fork, Marsh Creek, and Rock Creek in McCreary County; Sinking Creek, in Laurel County and Laurel Fork in Whitley County. The critical habitat designation became effective on August 31, 2004 (69 FR 53136 – 53180). The Cumberland elktoe exists in localized portions of the Cumberland River system in Kentucky and Tennessee. Presently, these species and their habitats are being impacted by deteriorated water quality, primarily resulting from poor land-use practices. Because the species have such restricted ranges, they are vulnerable to toxic chemical spills.

The Cumberland elktoe is known to exist in only three populations, two of which are in Kentucky. They persist in the middle section of Rock Creek, the upper portions of the Big South Fork Cumberland River basin and in Marsh Creek in McCreary County. Marsh Creek likely contains the best surviving elktoe population. This species appears to prefer habitats that range from medium-sized streams to large rivers that contain sand and mud substrata interspersed with cobbles and large boulders (Parmalee and Bogan 1998).

B.5 Cumberlandian combshell

Critical habitat for the Cumberlandian combshell is found in the Big South Fork in McCreary County and Buck Creek in Pulaski County. The designated habitat became effective on August 31, 2004 (69 FR 53136 – 53180). Historically, this species was distributed throughout the Cumberlandian region of the Tennessee and Cumberland River systems in Alabama, Kentucky, Mississippi, Tennessee, and Virginia (USFWS, 2003; 2004). Little else is known ecologically of this species other than it formerly was fairly common throughout its geographic range.

Populations are currently known from Buck Creek in Kentucky through a few miles of the Big South Fork Cumberland River in Kentucky and Tennessee and in very low numbers in the Powell and Clinch rivers in Virginia and Tennessee (USFWS, 1997). Currently, it is restricted to five stream reaches (USFWS, 2003; 2004). It has been extirpated from a large percentage of its former range (likely over 80%). TVA data indicates that populations continue to decline (USFWS, 2003; 2004). It has been eliminated from the mainstem of the Tennessee and Cumberland Rivers and several tributaries. The present populations are threatened by the adverse impacts of coal mining, poor land-use practices, and pollution, primarily from nonpoint source pollution.

With development, watersheds become more impervious, resulting in increased storm-water runoff into streams and as much as a doubling in annual flow rates in completely urbanized streams. Impervious surfaces may reduce sediment input into streams but result in channel instability by accelerating storm-water runoff, which increases bank erosion and bed scouring (NatureServe 2014).

B.6 Oyster mussel

Critical habitat for the Oyster mussel is found in the Big South Fork in McCreary County and Buck Creek in Pulaski County (69 FR 53136 – 53180, August 31, 2004). This species is somewhat sessile with only limited movement in the substrate. Passive downstream movement may occur when mussels are displaced from the substrate during floods. Major dispersal occurs while glochidia are encysted on their hosts (NatureServe, 2014).

The greatest threat to this species in the Cumberlandian Region is habitat alteration. Principal causes include impoundments, channelization, pollution, and sedimentation that have altered or eliminated those habitats that are essential to the long-term viability of many riverine mussel populations. Impoundments result in the elimination of riffle and shoal habitats, disruption of a river's ecological processes (flooding, loss of bottom stability, bank sloughing), elimination of current and the covering of rocky and sand substrates by fine sediments, and alteration of downstream water quality and riverine habitat. Daily discharge fluctuations, bank sloughing, seasonal oxygen deficiencies, cold-water releases, turbulence, high silt loads, and altered host fish distribution have contributed to limited mussel recruitment and skewed demographics. Impoundments, as barriers to dispersal, contribute to the loss of local populations by blocking post-extirpation recolonization. Population losses due to impoundments have contributed more to the decline of the Oyster mussel than any other single factor (USFWS, 2004).

Dredging and channelization activities have profoundly altered riverine habitats nationwide, with effects on streams. Channel construction for navigation has been shown to increase flood heights, thus exacerbating flood events that transport large quantities of sediment with adsorbed contaminants to streams. The entire length of the Tennessee River and much of the Cumberland River is maintained as a navigation channel with a series of locks and dams--nine on the Tennessee River and four on the Cumberland River. Channel maintenance activities continue to cause substrate instability and alteration in these rivers and may serve to diminish what habitat remains for the recovery of riverine species (USFWS, 2004).

The oyster mussel has declined (> 80%) to a few disjunct occurrences from what was a much more widespread historic distribution. Populations are discontinuous in nine tributaries and it is rare at these localities with evidence of decline (NatureServe 2014). Historically, this species was distributed throughout the Cumberlandian region of the Tennessee and Cumberland River drainages in Alabama, Georgia, Kentucky, North Carolina, Tennessee, and Virginia in 82 localities (USFWS, 2003; 2004). Current population size is difficult to estimate, but TVA qualitative surveys and quantitative estimates of density have been very low and continue to decline. Barr et al. (1994) determined (based on 1981 survey data) that viable populations exist in the Big South Fork (Scott County, Tennessee and McCreary County, Kentucky) (USFWS, 2003; 2004).

Agricultural sources of chemical contaminants are considerable and include two broad categories--nutrients and pesticides. Nutrient enrichment generally occurs as a result of runoff from livestock farms and feedlots and from fertilizers used on row crops. Pesticides, primarily from row crops, are a major source of agricultural contaminants. (NatureServe 2014).

B.7 Rabbitsfoot

Critical habitat for the Rabbitsfoot mussel is found in the Tennessee River, Ohio River, Green River and Red River (proposed rule. 77 FR 63439 – 63536). The rule for proposed designation of critical habitat became effective on October 16, 2012.

Rabbitsfoot populations are considered to be extant in 46 streams in 13 states and 5 USFWS regions including the Cumberland River System in Kentucky. Extant rabbitsfoot populations occur in Kentucky's Ohio River, South Fork Kentucky River, Green River, Barren River, Rough River, Red River and Tennessee River. The greatest threat to this species in the Cumberlandian region is habitat alteration. Principal causes include impoundments, channelization, pollution, and sedimentation (NatureServe 2014).

B.8 Fluted kidneyshell

Critical habitat for the Fluted kidneyshell is found in Horse Lick Creek, Middle Fork Rockcastle River, Rockcastle River, Buck Creek, Rock Creek, Little South Fork Cumberland River, and Big South Fork Cumberland River (77 FR 60803 – 60882). The rule for designation of critical habitat became effective on September 26, 2013.

The Fluted kidneyshell is restricted to the Cumberland River in Kentucky. Currently it is limited to nine streams in the Cumberland River system (six isolated populations) and seven streams (four isolated populations) in the Tennessee River system. Cumberland River system tributaries with extant populations include the Middle Fork Rockcastle River, Horse Lick Creek, Buck Creek, Rock Creek, Kennedy Creek, Little South Fork, Big South Fork, Wolf River and West Fork Obey River. The decline of the fluted kidneyshell in the Cumberlandian Region is primarily the result of habitat loss and degradation.

C. Individual Critical Habitat and Primary Constituent Element (PCE) Requirements

Alasmidonta atropurpurea, Cumberland elktoe
Epioblasma brevidens, Cumberlandian combshell
Epioblasma capsaeformis, Oyster mussel
Quadrula cylindrica cylindrica, Rabbitsfoot
(69 FR 53136, August 31, 2004)

(1) Primary Constituent Element 1—Permanent, flowing stream reaches with a flow regime (i.e, the magnitude, frequency, duration, and seasonality of discharge over time)

necessary for normal behavior, growth, and survival of all life stages of the mussels and their host fish;
(2) Primary Constituent Element 2—Geomorphically stable stream and river channels and banks (structurally stable stream cross section);
(3) Primary Constituent Element 3—Stable substrates, consisting of mud, sand, gravel, and/or cobble/boulder, with low amounts of fine sediments or attached filamentous algae;
(4) Primary Constituent Element 4—Water quality (including temperature, turbidity, oxygen content, and other characteristics) necessary for the normal behavior, growth, and survival of all life stages of the four mussels and their host fish; and
(5) Primary Constituent Element 5—Fish hosts with adequate living, foraging, and spawning areas for them.

Quadrula cylindrica cylindrica, Rabbitsfoot (Updated Critical Habitat Rule)
(77 FR 63440, October 16, 2012)

(1) Primary Constituent Element 1—Geomorphically stable river channels and banks (channels that maintain lateral dimensions, longitudinal profiles, and sinuosity patterns over time without an aggrading or degrading bed elevation) with habitats that support a diversity of freshwater mussels and native fish (such as, stable riffles, sometimes with runs, and mid-channel island habitats that provide flow refuges consisting of gravel and sand substrates with low to moderate amounts of fine sediment and attached filamentous algae);
(2) Primary Constituent Element 2—A hydrologic flow regime (the severity, frequency, duration, and seasonality of discharge over time) necessary to maintain benthic habitats where the species are found and to maintain connectivity of rivers with the floodplain, allowing the exchange of nutrients and sediment for maintenance of the mussel's and fish host's habitat, food availability, spawning habitat for native fishes, and the ability for newly transformed juveniles to settle and become established in their habitats;
(3) Primary Constituent Element 3—Water and sediment quality (including, but not limited to, conductivity, hardness, turbidity, temperature, pH, ammonia, heavy metals, and chemical constituents) necessary to sustain natural physiological processes for normal behavior, growth, and viability of all life stages;
(4) Primary Constituent Element 4—The presence, abundance and identity of fish hosts necessary for recruitment of the Rabbitsfoot are currently unknown. The occurrence of natural fish assemblages, reflected by fish species richness, relative abundance, and community composition, for each inhabited river or creek will serve as an indication of appropriate presence and abundance of fish hosts until appropriate host fish can be identified; and
(5) Primary Constituent Element 5—Either no competitive or predaceous invasive (nonnative) species, or such species in quantities low enough to have minimal effect on survival of freshwater mussels.

Ptychobranchus subtentum, Fluted kidneyshell (77 FR 60803, October 4, 2012)

(1) Primary Constituent Element 1—Riffle habitats within large, geomorphically stable stream channels (channels that maintain lateral dimensions, longitudinal profiles, and sinuosity patterns over time without an aggrading or degrading bed elevation);

(2) Primary Constituent Element 2—Stable substrates of sand, gravel, and cobble with low to moderate amounts of fine sediment and containing flow refugia with low shear stress;
(3) Primary Constituent Element 3—A natural hydrologic flow regime (the magnitude, frequency, duration, and seasonality of discharge over time) necessary to maintain benthic habitats where the species are found, and connectivity of rivers with the floodplain, allowing the exchange of nutrients and sediment for habitat maintenance, food availability for all life stages, and spawning habitat for native fishes;
(4) Primary Constituent Element 4—Water quality with low levels of pollutants and including a natural temperature regime, pH (between 6.0 to 8.5), oxygen content (not less than 5.0 milligrams per liter (mg/L)), hardness, and turbidity necessary for normal behavior, growth, and viability of all life stages; and
(5) Primary Constituent Element 5—The presence of abundant fish hosts necessary for recruitment of the fluted kidneyshell.

IX. Species Accounts

A. Mammals

A.1 Gray bat

The Gray bat was listed as endangered on April 28, 1976 (41 FR 17736 17740). The range extends from southeastern Kansas and central Oklahoma east to western Virginia and western North Carolina, and from Missouri, Illinois, and Indiana south to southern Alabama and northwestern Florida and occurs primarily in the cave region of Missouri, Arkansas, Kentucky, Tennessee, and Alabama. Summer and winter ranges are essentially the same. (Decher and Choate 1995).

These bats forage parallel to streams (Caire et al. 1989) and are adapted to forest foraging. The energy demands on adult females are tremendous during lactation, and individual females sometimes feed continuously for seven or more hours per night (Tuttle and Stevenson, 1977).

Pesticides represent a major threat to the Gray bat (Clark et al. 1978, 1980, 1982) and bats consume moths with dieldrin. Juvenile bats receive concentrated amounts through the female's milk.The rapid fat utilization in juveniles because of the stress of flight initiation can cause fatal concentrations in brain tissues (Clark et al. 1978). Dieldrin was banned in 1974, but provisions were made to use existing stocks. Clark et al. (1980) documented deaths in gray bats from heptachlor residues reflecting a change by local farmers from aldrin to heptachlor as stocks of aldrin have become depleted.

Destruction of food, foraging habitats, and caves is also a concern for the Gray bat. Mayfly larvae are susceptible to aquatic pollution, turbidity, and siltation caused by strip mines in the watershed or farming practices (Fremling 1968, Tuttle 1979). Deforestation of the watershed reduces foraging habitat (Tuttle and Stevenson, 1977). Young gray bats use the forest near the cave entrance for cover while perfecting flight abilities (Tuttle 1976). Both juveniles and adults use forested areas for protection from predators, specifically screech owls (Tuttle 1979). Impoundment of waterways has submerged important cave sites and made other caves more accessible to humans (Barbour and Davis 1969, Tuttle 1979, Brady et al. 1982).

Natural calamities, such as submersion of the cave during a flood or a natural cave-in, also affect bat populations (Tuttle 1979). Flood frequency and magnitude can be affected by channelization and other human activities. The elimination of colonies that were disrupted or deliberately destroyed when their caves were commercialized or entered repeatedly by explorers, scientists, or vandals has led to their decline (04/21/1975 40 FR 17590 17591). Bats consume insects (Lepidoptera, Coleoptera, and Diptera) selectively and opportunistically. They take advantage of taxa emergences and also eat a variety of other taxa in smaller quantities (Best et al. 1997).

A.2 Indiana bat

The Indiana bat was listed as an endangered species on March 11, 1967 and is currently listed as endangered under the Endangered Species Act of 1973, as amended. The majority of the population hibernates at relatively few sites, including several caves and one mine in Missouri, southern Indiana, and Kentucky (Brady et al. 1983, USFWS 1999).

A significant threat to the Indiana bat is human disturbance at winter caves, which causes aroused bats to deplete energy reserves (Twente 1955, Mohr 1972, Engel et al. 1976). Vandalism and indiscriminant killing have been a problem at some caves. Commercialization of caves result in excessive disturbance (Mohr 1972) or intentional elimination by cave owners (Hall 1962). Other threats include exclusion of bats by poorly designed gates (Long's Cave in Mammoth Cave National Park, Kentucky), changes in cave temperatures induced by opening additional entrances (Matthews and Moseley 1990) or poorly designed barriers to human access (Richter et al. 1993). Improperly constructed gates can alter the air flow, trap debris, and block the entrance by not allowing enough flight space (Brady et al. 1982). Altered exchange of air with the outside environment can cause significant changes in cave temperature and humidity and may cause the bats to abandon the cave (Tuttle 1977).

Despite protection at overwintering sites, populations continue to decrease in several portions of their range, suggesting that the species is being negatively affected by disturbance or loss of summer habitat. Loss and degradation of summer habitat and roost sites due to impoundment, stream channelization, housing development, clear cutting for agricultural use (Herkert 1992), or incompatible forest management practices that result in a shortage of the microhabitats used for maternity roosts may be the primary factors in recent population declines (Sparks et al. 2005).

Flying insects are the typical prey items; diet reflects prey present in available foraging habitat. The bat forages along river and lake shorelines, in the crowns of trees in floodplains (Humphrey et al. 1977), and in upland forest (Brack and LaVal 1985).

The most significant range wide threats to the Indiana bat have been habitat loss/degradation, forest fragmentation, winter disturbance, and environmental contaminants. In addition to these threats, climate change and white-nose syndrome are increasingly being identified as significant threats to the future recovery of the Indiana bat and its congeners (Indiana Bat 5-Year Review: Summary and Evaluation 2009).

A.3 Northern long-eared bat

The Northern long-eared bat was listed as proposed endangered on October 2, 2013. This bat is widely but patchily distributed in the eastern and north central United States and adjacent southern Canada, from Newfoundland and eastern Quebec south through New England and the mountains of Virginia, North Carolina, South Carolina, and Georgia to the north central panhandle of Florida (formerly) and northwestward through Alabama, northern Arkansas, the eastern Great Plains, and the western Canadian provinces, to northeastern British Columbia and southern Northwest Territories (Barbour and Davis 1969, Harvey 1992, van Zyll de Jong 1985, Hall 1981).

The general summer and winter ranges appear to be identical (Barbour and Davis 1969). This species is more common in the northern part of the range than in the south (Harvey 1992), and it is rare in the northwestern portion of the range (Nagorsen and Brigham 1993, Caceres and Barclay 2000). It is reported uncommon in Indiana, Kentucky, Tennessee, and Wisconsin (Mumford and Cope 1964, Harvey 1991, Jackson 1961), more common in northern Michigan than in southern Michigan (Kurta 1982), and quite common in New York (Hamilton and Whitaker 1979).

The most serious threat is white-nose syndrome (WNS), an often (but not always) lethal condition caused by a fungal pathogen (*Geomyces destructans*). WNS was first noticed in 2006 in New York. Since its initial discovery, WNS has spread rapidly and now occurs throughout most of the northeastern United States and adjacent southeastern Canada. WNS affects *Myotis septentrionalis* and several other bat species (Gargas et al. 2009) and resulted in more than a million bat deaths in the northeastern United States in just 5 years.

Loss, degradation, and fragmentation of mature forest habitat (associated with various kinds of human activities, such as logging; oil, gas, and mineral development; and wind energy development) also may be a significant threat (Center for Biological Diversity 2010, USFWS 2011). Mortality caused directly by wind turbines may pose a significant threat in some areas (USFWS 2011).

This species is sensitive to disturbance during hibernation (Thomas 1995). Frequently aroused bats may deplete their energy reserves. Nursery colonies are very sensitive to disturbance by humans; bats may move to an alternate roost after a single examination, even if no attempt is made to capture the bats (Layne 1978).

Populations of this species in New York, Massachusetts, and Vermont declined 93 percent overall in the few years since white-nose syndrome was first discovered (Langwig et al. 2009). Small, highly fragmented, or young forests that provide limited areas of sub-canopy foraging habitat may not be suitable. Young forests may also lack appropriate nursery sites. A lack of suitable hibernacula may prevent occupancy of areas that otherwise have adequate habitat (Kurta 1982).

The Northern long-eared bat is an opportunistic insectivore (Kunz 1973). Prey composition varies widely among sites and seasons and their diet includes Lepidoptera, Coleoptera, Neuroptera, Diptera, Hymenoptera, Homoptera, and Hemiptera (Whitaker 1972, LaVal and LaVal 1980, Griffith and Gates 1985). The presence of green plant material in some individuals, suggesting that some insects may have been gleaned from vegetation (Fenton 1982).

Foraging typically occurs in forested habitats, above and below the canopy, over forest clearings and occasionally over water. Eleven individuals (10 males, 1 female) tagged with chemical lights observed during the summer in Missouri (LaVal et al. 1977), foraged almost exclusively among the trees of hillside and ridge forests, rather than utilizing floodplain and riparian forests. Foraging bats doubled back frequently and only slowly moved out of the observation area. In Iowa, Kunz (1973, 1971) found primarily females foraging in mature deciduous uplands with adjacent deep ravines and in a disturbed riparian area with an adjacent floodplain and agricultural lands (NatureServe. 2014).

A.4 Virginia big-eared bat

The Virginia big eared bat was listed as endangered on November 30, 1979 50 (44 FR 69206 69208) and the effective date of that rule was December 31, 1979. This bat is found in three separate populations, centered in eastern Kentucky, southwestern Virginia, and eastern West Virginia, but many caves within this region have been abandoned. Kentucky now comprises fewer than 500 bats. Some of these bats have been killed for fun. In addition, well-meaning biologists and spelunkers, observing the bats for scientific or educational purposes, have caused disturbances and subsequent population reductions because of the high sensitivity of these species. The growing popularity of spelunking is a tremendous threat to these bats because they are very intolerant of disturbance. Forest defoliation by gypsy moth could adversely affect native Lepidoptera and impact bat population (Sample and Whitmore 1993).

In Kentucky, the Virginia big eared bat is often detected in old fields and above cliffs (Burford and Lacki 1995) where they feed principally on moths. They forage over fields and woods, with individuals routinely traveling 3-5 miles from roost cave to foraging area. The Virginia big eared bats were also observed foraging in corn, hay and alfalfa fields. Forest insects comprise a substantial portion of the diet (Virginia big eared bat 5 year review 2008; Sample and Whitmore 1993).

B. Birds

B.1 Rufa red knot

The Rufa red knot was listed as threatened on January 12, 2015. From the perspective of migration, this subspecies could be regarded as having only one or few major occurrences, since most of the population migrates through Delaware Bay (Morrison et al. 2004) and most of the population spends the boreal winter in a small area of Tierra del Fuego (Niles et al. 2007).

A major threat to the red knot is the increased commercial harvest of horseshoe crabs for use as bait in eel and conch fisheries; especially in the Delaware Bay region in the 1990s (Walls et al. 2002, Morrison et al. 2004, Niles et al. 2007) which has led to a reduction in horseshoe crab populations, and a consequent reduction in red knot food resources (horseshoe crab eggs).

Additional threats to flocks in winter habitat or migration stops include oil pollution, disturbance by humans, and habitat loss through reclamation for development (Niles et al. 2007).

Experts from the Fish and Wildlife Service and from the [American Bird Conservancy](#) (ABC), a nonprofit advocacy group that has petitioned for the bird's protection under the ESA for eight years now, all point to the scarcity of horseshoe crabs in the Delaware Bay region as a primary factor in the red knot's decline. As Fish and Wildlife spokesperson Meagan Racey explained, "Delaware Bay is the only area in which knots feed on horseshoe crab eggs, and it hosts the largest concentration of knots in the world during the spring stopover that lines up with horseshoe crab spawning."[4]

The migration stops of red knots that spend the boreal winter in Tierra del Fuego and Patagonian Argentina (subspecies *Rufa*) are mainly along the Atlantic coast of South America (mainly Chile, Argentina, and Brazil) and the Atlantic and Gulf of Mexico coasts of North America (González et al. 2006), including staging areas on the coasts of Hudson and James Bays (Harrington 2001). Knots that visit Delaware Bay in spring come mostly from South America, and these have strong fidelity to migration stopover sites. Those that winter in Florida are underrepresented during migration in New Jersey and Massachusetts.

Red knots are restricted to the ocean coasts during winter, and occur primarily along the coasts during migration. However, small numbers of Rufa red knots are reported annually across the interior United States (i.e., greater than 25 miles from the Gulf or Atlantic Coasts) during spring and fall migration—these reported sightings are concentrated along the Great Lakes, but multiple reports have been made from nearly every interior State (eBird.org 2012).

The historic range of the red knot includes Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Louisiana, and Texas.

EPA could find no reference to Rufa red knot accounts in Kentucky.

B.2 Piping plover

The piping plover was originally listed as a threatened species on December 11, 1985 (50 F.R. 50726-50734). Piping plovers are small shorebirds approximately seven inches long with sand-colored plumage on their backs and crown and white underparts. According to Natural Heritage Program records, piping plovers may migrate through Kentucky to feed in the area of the Kentucky Lake but they are extirpated or possibly extirpated (NatureServe. 2014). Piping plovers feed on worms, crustaceans, insects, and some small mussels. They require wide, flat, open sandy banks with very little grass or other vegetation. Nesting may occur near small streams or wetlands. Strong threats to this species are related primarily to disturbance by human activity, predation, and development. Primary threats are destruction and degradation of summer and

[4] http://news.nationalgeographic.com/news/2013/10/131003-rufa-red-knot-threatened-endangered-migrating-birds/

winter habitat, shoreline erosion, human disturbance of nesting and foraging birds, and predation (Burger 1993).

B.3 Whooping crane

The whooping crane was listed as endangered, nonessential experimental population on March 11, 1967. There is one self-sustaining population that nests in Canada and winters primarily along the Texas coast. There are two additional reintroduced populations (one migrating from Wisconsin to Florida, one non-migratory in Florida). Historically the crane was much more widespread. The total wild population in 2006 was 338 and there were about 135 birds in captive flocks (NatureServe 2015).

Canada is home to 100% of the naturally-occurring global breeding population of this species. Although never common, its population dipped to only 14 adult birds early in the last century, at which point the species was at the brink of extinction. Conservation efforts in Canada and the U.S. not only rescued the remnant population from extinction, but later resulted in population increases. (NatureServe 2015).

To help ensure persistence of the species, efforts to establish wild flocks of captive-bred individuals outside Canada have been underway for several decades. Nevertheless, Canada's breeding population is still very small and is confined to a limited breeding area and only one wintering location. This situation exposes it to catastrophic natural events (e.g. droughts, hurricanes) and a variety of ongoing anthropogenic threats (e.g. loss and degradation of coastal wetland habitats on the wintering grounds, oil spills in coastal areas, and collisions with power lines and structures during migration). Last, because of delayed sexual maturity and a naturally low annual reproductive output, the population of this species has an inherently weak capacity to rebound from pressures that reduce survivorship or reproductive success (NatureServe 2015). Historically, population declines were caused by shooting and destruction of nesting habitat in the prairies from agricultural development. The species was listed as endangered because of low population numbers, slow reproductive potential (sexual maturity is delayed and pairs average less than 1 chick annually), cyclic nesting and wintering habitat suitability, a hazardous 4,000 kilometer migration route that is traversed twice annually, and many human pressures on the wintering grounds. Threats to the captive flock include disease, accidents, and limited genetic material. [Source: CWS and USFWS 2007]

During summer the cranes feed on insects, crustaceans, and berries. Their winter diet includes grains, acorns, wolfberry fruit, insects, crustaceans (e.g., blue crab, crayfish), mollusks, fishes, amphibians, reptiles and marine worms (Hunt and Slack 1989). Blue crabs obtained from flooded tidal flats and sloughs dominate the crane diet in Texas until January. Then the cranes move to shallow bays and channels to eat clams and an occasional crab (Matthews and Moseley 1990). Radio-marked migrants fed primarily in a variety of croplands (Ehrlich et al. 1992).

B.4 Interior least tern

The interior least tern was listed as Endangered in Kentucky and several other states on May 28, 1985 (50 F.R. 21792). The least tern is the smallest member of the tern family and has a wing span of twenty inches. The least tern eats small fish such as minnows, shiners, stone rollers, mosquito fish, gizzard shad, sunfish, and small carp, in addition to crustaceans, insects, mollusks, and annelids. Interior least terns nest on Mississippi River and Ohio River islands in western portions of Kentucky. They are the only endangered species of bird which nests in Kentucky. Changes in flooding regimes of rivers have reduced the number of nesting sites available. Flooding is the primary cause of nest lost, but some nests are lost to predators and disturbance.[5] Interior populations of the least tern, formerly well distributed in the Mississippi Basin, now survive only in scattered remnants; habitat has been decimated by extensive water management projects and increased human use of beaches and sandbars.

In Kentucky, the interior least tern is a summer resident. Barren sand bars are the least tern's favored nesting habitat. Non-vegetated sand bars are less stable and are formed and removed through dynamic flows of large sandy-bottomed rivers. Navigation dams have caused changes in the rivers resulting in the loss of sand and gravel bars. Recreational use of the remaining sandbars makes them less suitable for least tern nesting.[6] [7]

Habitat loss due to development and habitat alteration, such as dams along the interior least tern's habitat, are the critical problems this population is encountering. The majority of actions in the least tern recovery plan focus on habitat protection or restoration. A recovery plan has been published by the USFWS (USFWS September 1990).

C. Fish

C.1 Diamond darter

The Diamond darter was listed as endangered on July 26, 2013. In total about 122.5 river miles in Kanawha and Clay Counties, West Virginia, and Edmonson, Hart, and Green Counties, Kentucky, have been designated as critical habitat.

The diamond darter is a small fish that is a member of the perch family (Percidae). Diamond darters bury into the sand of a stream bottom and ambush the insects that serve as their prey. Adult diamond darters are benthic invertivores, feeding primarily on stream bottom-dwelling invertebrates. This species was historically distributed throughout the Ohio River Basin including the Muskingum River in Ohio; the Ohio River in Ohio, Kentucky, and Indiana; the Green River in Kentucky; and the Cumberland River Drainage in Kentucky and Tennessee. This darter has been extirpated from all of these streams and is now known to occur only within the lower Elk River in West Virginia.

Habitat includes clean sand, gravel, and cobble runs of small to medium rivers (Page and Burr 2011). The impoundment of rivers in the Ohio River Basin, such as the Kanawha, Ohio, and Cumberland, has eliminated much of the species' habitat and isolated the existing population from other watersheds that the species historically occupied. This species no longer occurs in

[5] http://www.johnbrunjes.com/?p=3414

[6] http://legacy.westkentucky.kctcs.edu/facstaff/web/blee/KYE/KYEDocuments/interiorleasttern.htm

[7] http://www.fws.gov/southeast/5yearReviews/5yearreviews/interiorLeastTern5yrReivew102413.pdf

most of its historical range (Welsh et al. 2009); was last collected in Kentucky in 1929 (Burr and Warren 1986) and in Tennessee in 1939 (Etnier and Starnes 1993). This fish needs clean water without too much silt (FR Vol. 78, No. 144, July 26, 2013 pages 4507-45095).[8]

C.2 Relict darter

The relict darter was listed as endangered on October 27, 1993. It occurs in a very small area of the Bayou du Chien system in western Kentucky. A small population exists with very limited spawning sites which is threatened by poor water quality and general habitat deterioration. The range of the relict darter includes only the Bayou du Chien system in Graves and Hickman counties of western Kentucky (Page et al. 1992; Piller and Burr 1998, 1999; Page and Burr 2011). Surveys in the 1990s found the species in an area encompassing approximately 35 stream-kilometers (Piller and Burr 1998, 1999). Jelks et al. (2008) categorized this species as endangered due to (1) present or threatened destruction, modification, or reduction of a taxon's habitat or range and (2) restricted range.

Adult relict darters (*Etheostoma chienense*) inhabit shallow, clear, low-flow reaches, usually associated with gravel, sand, and leaf-litter substrates near fallen tree branches, undercut banks, or overhanging stream-bank vegetation (Piller and Burr 1999; USFWS 1993). The relict darter is sensitive to declines in pH (USFWS 2007b). It uses a complex form of reproduction called "egg-clustering" in which eggs are laid in the nest built under a submerged object such as a flat stone. A survey conducted on this species in Bayou de Chien, Kentucky, found limited nesting resources throughout the drainage (Piller and Burr 1999). Relict darter prey are thought to consist mainly of aquatic insects and small crustaceans (NatureServe 2014g).

The single known spawning area is in an unprotected agricultural area (Page et al. 1992). Habitat has been and continues to be impacted by poor water quality and habitat deterioration resulting from stream channelization, siltation caused by poor land use practices, and by other water pollutants (USFWS 1992, 1993). Warren et al. (1994) reported that "probable historic reasons that may have restricted the spawning area, habitat, and distributional extent of the relict darter include: channelization of extensive reaches of the mainstem of Bayou du Chien with associated homogenization of instream habitat as well as dewatering of floodplain tributaries; ditching of tributaries and removal of shade-producing riparian vegetation and associated decrease in habitat and increase in maximum stream temperatures; increased siltation associated with poor agricultural practices; and deforestation and drainage of riparian wetlands with related decreases in instream low flow, especially in potential spawning areas."

C.3 Duskytail darter

The Duskytail darter was listed as an "endangered, nonessential experimental population" on April 27, 1993. It has a small range (one occurrence) in Virginia. In Kentucky, this fish is only found in the section of the Big South Fork of the Cumberland River within the Big South Fork National Recreation Area. Duskytail darter populations are known to exist in only three other

[8] http://conservationfisheries.org/index.php/species/all-species/crystallaria-cincotta-diamond-darter/

locations: Citico Creek, TN, Little River, TN, and Copper Creek, VA. Two other populations of this species are now believed to be extirpated.

The Duskytail darter is found in large clear streams and moderate sized rivers. It prefers pools one to four feet in depth that are located at the heads of riffles. Pool bottoms are generally covered with large rocks overlying sand and gravel. The Duskytail is only found in areas with little or no siltation. Duskytails spend most of their time on the bottom of the stream. They feed on small crustaceans and aquatic insect larvae.

Duskytail darter (*Etheostoma percnurum*) habitat includes silt-free, rocky pools in large rivers and streams (58 FR 25758, April 27, 1993). Duskytail darters are known to be insectivores, and consist mainly of microcrustaceans, chironomid larvae, and heptageniid nymphs. The abundance of *Stenonema* and *Stenacron* mayflies in the diet suggests that the duskytail darter feed on the undersides of stones (Layman 1991).

Impoundments, siltation associated with poor land-use practices, coal mining, and logging have contributed to the decline of this species.[9]

C.4 Cumberland darter

The Cumberland darter was listed as endangered on August 9, 2011. It has a small, reduced range in the Cumberland River drainage above Cumberland Falls in eastern Kentucky and adjacent Tennessee. Currently, the species is known from 15 localities in a total of 13 streams in Kentucky (McCreary and Whitley counties) and Tennessee (Campbell and Scott counties). All 15 extant occurrences are restricted to short stream reaches, with the majority believed to be restricted to less than 1.6 kilometers of stream. These occurrences are thought to form six population clusters (Bunches Creek, Indian Creek, Marsh Creek, Jellico Creek, Clear Fork, and Youngs Creek), which are geographically separated from one another by an average distance of 30.5 stream kilometers (USFWS 2011).

This fish inhabits shallow water in low velocity shoals and backwater areas of moderate to low gradient stream reaches with stable sand or sandy-gravel substrata. It is not found in areas with cobble or boulder substrata. All specimens that have been collected in recent years have been found in less than 15 centimeters of water (Laudermilk and Cicerello 1998).

Clean, silt-free, cool, flowing water is necessary for the Cumberland darter (*Etheostoma susanae*) to successfully complete its life cycle. The Cumberland darter[10] has been found in perennial second-to-fourth order streams, inhabiting pools or shallow runs of low-to-moderate gradient stream segments with stable sand, silt, or sand-covered bedrock substrates. It is reported that individuals travel up to several miles between temporary stream habitats and permanent pools in downstream reaches prior to spawning. Stressors to the Cumberland darter include low flow and poor water quality (77 FR 63604, October 16, 2012). In general, there is limited information about the feeding habits of the Cumberland darter, but their habits are likely to be

[9] http://legacy.westkentucky.kctcs.edu/facstaff/web/blee/KYE/KYEDocuments/duskytaildarter.htm

[10] Little information is available for the Cumberland darter. When information is limited, analyses by the USFWS rely on information on its close relative, the Johnny darter (*Etheostoma nigrum*) (Starnes and Starnes 1979).

similar to the Johnny darter (*Etheostoma nigrum*), a congeneric species. Johnny darters are diurnal sight feeders that feed on prey including midge larvae, mayfly nymphs, caddisfly larvae, and microcrustaceans. Juveniles likely feed on planktonic organisms and other small invertebrates (77 FR 63604, October 16, 2012).

Little is known about the reproductive habits of the Cumberland darter, but they are, again, likely to be similar to those of the related Johnny darter. The Johnny darter spawns between April and June when the males migrate to spawning areas to establish territories and build nests under submerged objects (e.g., boulder or woody debris), removing silt and fine debris. After the eggs are laid, the male fans the area periodically to remove silt. In the context of reproductive activities, Cumberland darters are found in stable, second- to fourth-order streams containing gently flowing run and pool habitats with sand and bedrock substrates, boulders, large cobble, woody debris, or other cover and that are relatively silt-free and connected to other similar habitats (77 FR 63604, October 16, 2012).

It is threatened primarily by sedimentation and other water pollution resulting from coal mining, logging, agriculture, and development. Habitat loss and modification represent significant threats to the Cumberland darter. Severe degradation from physical habitat disturbance, and contaminants threaten the habitat and water quality on which the Cumberland darter depends. Sedimentation from coal mining, logging, agriculture, and development sites within the upper Cumberland basin negatively affect the Cumberland darter by reducing growth rates, disease tolerance, and gill function; reducing spawning habitat, reproductive success, and egg, larvae, and juvenile development; modifying migration patterns; reducing food availability through reductions in prey; and reducing foraging efficiency. Contaminants associated with coal mining (metals, other dissolved solids), domestic sewage (bacteria, nutrients), and agriculture (fertilizers, pesticides, herbicides, and animal waste) cause degradation of water quality and habitats through increased acidity and conductivity, instream oxygen deficiencies, excess nutrification, and excessive algal growths.

C.5 Palezone shiner

The Palezone shiner was listed as endangered on April 27, 1993 (58 FR 25758 25763). The Recovery Plan was completed on July 7, 1997 (Recovery Plan 1997). The palezone shiner is a member of the Cyprinidae family. The species' food habits are unknown. There is little information regarding reproduction and development of the palezone shiner.

The palezone shiner occurs in large creeks and small rivers. The species inhabits flowing pools and runs of upland streams that have permanent flow; clean, clear water; and substrates of bedrock, cobble, pebble, and gravel mixed with clean sand (Starnes and Etnier 1980, Branson and Schuster 1982, Burr and Warren 1986, Ramsey 1986).

The palezone shiner has been known to occur in the Little South Fork of the Cumberland River (LSFCR), Wayne and McCreary Counties and Marrowbone Creek, Cumberland County (Starnes and Etnier 1980). It currently occurs in only two widely disjunct populations in the Paint Rock River in Jackson County, Alabama, and the Little South Fork of the Cumberland River in Wayne and McCreary Counties, Kentucky.

Three of the four known localities for the palezone shiner occur in streams on the periphery of the Cumberland Plateau. The distribution of the palezone shiner implies that the two remaining populations are remnants of a once more widespread distribution (Starnes and Etnier 1986).

Since about 1980, the lower third of Little South Fork of the Cumberland River (LSFCR) has been periodically subjected to toxic surface mine runoff (especially, elevated heavy metal concentrations). The impact of the discharge on the palezone shiner within this reach of the river is unknown, but recent (1990) sampling in this reach compared to past efforts (Harker *et al*. 1979, 1980, Branson and Schuster 1982) indicate the benthic fish community, both in terms of diversity and numbers of individuals, has been severely reduced, a probable result of direct mortality of adults and/or eggs, larvae, and juveniles. Upstream of the area receiving toxic mine discharge in LSFCR, the primary threats to the palezone shiner are brine discharges from oil wells (Harker *et al*. 1979, 1980) and poor land-use practices associated with increased siltation of the stream (road building, deforestation, destruction of riparian buffer strips).

The only known population of the palezone shiner (*Notropis albizonatus*) exists in Little South Fork, Kentucky, which borders the Daniel Boone National Forest (Warren and Brooks 1998). Palezone shiner habitat includes flowing pools and runs in streams with clean, clear water and substrate consisting of bedrock, cobble, pebble, gravel, and clean sand (USFWS 2013c). Their relatively short life-span make them more susceptible to short-term, local habitat alterations (NatureServe 2014h). A study found that palezone shiners feed primarily on fly larvae in the suborder Nematocera as well as other aquatic organisms such as small crustaceans, roundworms, aquatic mites, diatoms, and some plant material (USFWS 2013c).

C.6 Blackside dace

The Blackside dace was listed as threatened on June 12, 1987. It is a small minnow, with a maximum length of about 3 inches that is restricted to headwater streams in southeastern Kentucky and northeastern Tennessee. It is restricted to small tributaries in the upper Cumberland River system including small tributaries in the Cumberland Plateau portion of the upper Cumberland River above Cumberland Falls and a few kilometers below (Etnier and Starnes 1993) in southeastern Kentucky (Bell, Harlan, Knox, Laurel, Letcher, McCreary, Pulaski and Whitley Counties) (USFWS 1988).

The species inhabits undisturbed, cool headwater streams with stable substrates, low in-stream conductivity, and sufficient in-stream cover. The area that the Blackside dace inhabits is known to be disturbed by resource extraction activities such as forestry, coal mining, agriculture, gas/oil well exploration, human development, and inadequate sewage treatment. All of these activities have contributed to degradation of streams within the range of the species.

The species is usually found in pools near undercut banks, large rocks, root mats, or other cover. The best populations of Blackside occur in silt-free streams in heavily forested watersheds with stable stream banks and undisturbed riparian zones. The species requires silt-free gravel bottoms for spawning. In the absence of silt-free bottoms, the species often spawns (April to June) in nests of other fish species, such as creek chubs and stonerollers.

Blackside dace (*Phoxinus cumberlandensis*) inhabit cool, small, upland tributaries with extensive cover (Starnes and Starnes 1981). They are reported to recolonize formerly degraded areas when habitat conditions improve (Rakes et al. 1999). Blackside dace feed on organic detritus, periphyton (diatoms and other algae), and invertebrates (Chironomidae and Hydropsychidae, NatureServe 2014i; Starnes and Starnes 1981).

Coal mining, in particular, often contributes metals and other dissolved solids that permanently affect water quality. If proper BMPs are implemented during these activities, potential impacts can be avoided or minimized. The range of the Blackside dace has been reduced and fragmented by surface coal mining. Populations occur in several dozen small, isolated stream reaches. It is threatened by siltation caused by human activities, impacts of unregulated acid mine drainage, impoundments, and possibly competition from an introduced dace.

Total adult population size is unknown but probably is at least several thousand. Most populations are small and consist of only a few individuals in short segments of suitable habitat (O'Bara 1990). The densest populations include an estimated 55-75 individuals per 100 square meters of stream (Starnes and Starnes 1981).

The southern redbelly dace (Phoxinus erythrogaster), a comparatively more recent (geologically) component of the upper Cumberland River basin fauna, is now present in many basin streams (Starnes 1981, Starnes and Starnes 1978). The Redbelly dace is believed to have outcompeted and displaced Blackside dace from some stream habitats where the water and habitat quality have been altered (i.e., stream bank modification, channel modification, and forest cover modification) to create warmer and more turbid conditions (Starnes 1981).

Introductions of non-native predaceous fishes (e.g., *Oncorhynchus mykiss*) may have a negative effect on the remaining populations (Leftwich et al. 1995). Remaining populations are small and isolated from each other by extremely degraded habitat, and the exchange of genetic material among some of these populations is likely infrequent or nonexistent. If isolation continues, some of the smaller populations may have insufficient genetic variability to maintain long-term viability (USFWS 1988).[11]

C.7 Pallid sturgeon

The pallid sturgeon was listed as an endangered species on September 6, 1990 (USFWS, 1990; 55 FR 36641). The species is a large river dweller that prefers sandy, turbid, free-flowing waters. This species is known to live up to 40 years. A recovery plan addressing the pallid sturgeon was approved by the USFWS on November 7, 1993 (USFWS, 1993). The plan focuses on the protection and restoration of pallid sturgeon habitat, gathering data for survival and recovery of the species, and captive propagation and reintroduction.

The diet of the pallid sturgeon includes aquatic invertebrates and some fish species. It once occupied a diverse assemblage of habitats found within the main channel and floodplain during flood flows of the Missouri and Mississippi Rivers. The pallid sturgeon may inhabit the waters at

[11] http://conservationfisheries.org/index.php/species/all-species/phoxinus-cumberlandensis-blackside-dace/

the confluence of the Ohio and Mississippi Rivers in far western Kentucky along Ballard, Carlisle, Fulton and Hickman counties. Given the low selenium concentration in fish from these rivers based on the EPA National Aquatic Resource Survey (NARS) Data (USEPA 2013), there is unlikely to be exposure, and that exposure is unlikely to result in selenium risk to the pallid sturgeon.

Pallid sturgeon (*Scaphirhynchus albus*) inhabit a variety of habitats consisting of diverse depths and water velocities, formed by braided channels, sandbars, sandflats, and gravel bars (USFWS 1998). Pallid surgeon are known to spawn in shallow rocky areas (Koch et al. 2012). There is evidence that pallid surgeon prefer dimly lit, turbid water and do not use clear-water riverine habitats. It is suggested that light intensity and photoperiod affect behavior, growth, and reproduction of the fish, but little information is available in the context of decreased turbidity being a threat to pallid sturgeon or the source of turbidity being a factor (Belvins 2011). Pallid sturgeon most frequently prefer sandy habitat, likely because of emerging invertebrates. In May, pallid sturgeon were found closer to gravel substrates, possibly to spawn (Koch et al. 2012). Based on a survey conducted on larval pallid sturgeon, surface and bottom water velocity could be an important attribute to larval survival (Hrabik et al. 2007). Pallid sturgeon are known to feed opportunistically on aquatic insects, crustaceans, mollusks, annelids, eggs of other fishes, and other fish (NatureServe 2014j). Their diet appears to shift from macroinvertebrates to fish over time, although the exact timing and at what life stage it happens is unknown (Grohs et al. 2009; USFWS 2014b; Wildhaber et al. 2011).

The Pallid sturgeon has declined due to hydrologic modification, and the destruction and alteration of its habitat. Channelization; levee, jetty, and dam construction; and control of river flow, velocity, volume, and hydroperiod have significantly reduced or eliminated pallid sturgeon habitat or severely impacted fish movement and spawning. Flood control of the large rivers has reduced sediment transport and snag development. In addition the reduction of sediment induced by hydrologic modifications has increased predation upon young pallid sturgeon by sight-feeding predators. Water pollution has had an impact on the species throughout its range. Human induced pollution such as organic waste from municipalities, packing houses, and stockyards has decreased the species along its range.

C.8 Shovelnose sturgeon

On September 1, 2010, the U.S. Fish and Wildlife Service, determined it was necessary to treat shovelnose sturgeon (*Scaphirhynchus platorynchus*) as threatened due to the similarity of appearance to the endangered pallid sturgeon (*Scaphirhynchus albus*) under the similarity of appearance provisions of the Endangered Species Act of 1973, as amended. The shovelnose sturgeon and the endangered pallid sturgeon are difficult to differentiate in the wild and inhabit overlapping portions of the Missouri and Mississippi River basins. Commercial harvest of shovelnose sturgeon has resulted in the documented take of pallid sturgeon where the two species coexist and is a threat to the pallid sturgeon.The shovelnose sturgeon, smallest of the ancient sturgeon species in North America, is similar in appearance to the pallid sturgeon. The Shovelnose has a flattened and shovel-shaped snout and is distinguished by pale, bony plates instead of scales, a reptile-like body, a sucker-type mouth and large barbels or whisker-like sensors next to its mouth. The Shovelnose uses its strongly fringed barbels to sense the river bottom and to identify prey, and then capture it with its protrusible, vacuum cleaner-like mouth. Prey consists of aquatic insects and invertebrates.

Shovelnose sturgeon can tolerate high turbidities and are usually found in the strong currents and deep channels of large rivers over sand and gravel substrates. They are apparently intolerant of the quiet waters of lakes and reservoirs, and dams restrict their movements. Shovelnose sturgeon frequent waters that are 6.5-23 feet deep and are relatively sedentary most of the time, but occasionally move long distances (as much as 7.5 miles in one day) exhibiting some homing behavior. During high water stages in the spring they frequent areas downstream of wing dams or other obstructions and remain near shore, while during summer low water levels they remain near mid-channel.

Shovelnose sturgeon are opportunistic feeders; taking any aquatic insects, mussels, worms, or crustaceans that are available. Spawning normally occurs from April through early July with mature Shovelnose migrating upriver to spawn over rocky substrates in flowing water between 66 and 70 °F. Well adapted as a bottom dwelling fish, the shovelnose sturgeon changes this habit by swimming near the surface during spawning. Weights at maturity range between 2 and 3 lbs, but some individuals have been recorded to weigh nearly 15 lbs. Females do not spawn every year, and spawning chronology is not readily evident. However, Shovelnose are known to hybridize with pallid sturgeon in the Missouri and lower Mississippi rivers, presumably because their former unique habitats have been altered or lost largely due to damming, altered hydrology, and channelization. This has forced the two species to share the same spawning sites, and since fertilization occurs externally hybridization occurs when the eggs and sperm of the two species mix in the water flowing over their spawning beds.

The Shovelnose sturgeon is strictly a freshwater species that was historically found throughout most of the Mississippi and Missouri river basins, from Montana south to Louisiana, and from Pennsylvania west to New Mexico. While the Shovelnose has not experienced the range reduction of some of the larger Mississippi River Valley sturgeons (i.e., lake and pallid sturgeons), it is no longer found in Pennsylvania, New Mexico, and large parts of Kansas, Kentucky, Tennessee, and other states where it was once abundant. Alteration of large rivers by channelization, construction of high dams, and construction of navigation locks and dams have contributed significantly to the decline of this species by blocking access to ancestral spawning grounds and by eliminating its requisite lotic habitat.

Alteration of large rivers and construction of locks and dams for navigation purposes have contributed significantly to the decline of Shovelnose sturgeon by blocking access to ancestral spawning grounds and by eliminating its requisite lotic habitat. In addition to impacts related to navigation, much of the habitat available to the Shovelnose sturgeon within its historic range, has also been altered by water resource development projects designed to provide for irrigation, public water supply, public recreation, and the production of electricity. Dams have blocked spawning migrations, isolated populations, destroyed rearing and spawning habitats, and altered food supply as well as changed flow, turbidity and temperature regimes (Dryer and Sandvol 1993) (Rasmussen 2001).

Shovelnose sturgeon (*Scaphirhynchus platorynchus*) inhabit deep channels and embayments of large turbid rivers; often over sand mixed with gravel or mud in areas with strong current. They feed mostly on bottom-dwelling immature aquatic insects, other benthic invertebrates, and fish eggs (NatureServe 2014k).

Historically, Shovelnose were apparently common in the Tennessee River system, all the way to the French Broad River on the Tennessee-North Carolina border before the Tennessee Valley Authority (TVA) reservoir system was constructed (Etnier and Starnes 1993). No recent records exist for either the Tennessee or Cumberland Rivers.

D. Crustaceans

D.1 Kentucky cave shrimp

The Kentucky cave shrimp was listed as endangered on October 12, 1983. It is a subterranean obligate, found in pools with silty bottoms and is a detritivore which feeds on “protozoans, algal cells, fungi, and other organic materials.” It is endemic to the Mammoth cave/Flint Ridge cave system in Kentucky and is found in pools with silty bottoms. Despite much study in the Mammoth Cave ecosystem, data on this species is scant.

The Kentucky cave shrimp feeds by grazing the surface of sediments in caves, consuming protozoans, algal cells, fungi, and other organic materials. The species has very specific habitat requirements - large, base level passages of caves characterized by slow flow, abundant organic matter, and coarse to fine grain sand and coarse silt sediments (5 year recovery plan, 2007). The species’ known distribution is limited to nine groundwater basins in the Mammoth Cave National Park region of central Kentucky (USFWS 1988). These groundwater basins include Echo River Spring, Ganter Spring, Running Branch Spring, Mile 205.7 Spring, Pike Spring, Double Sink (Sandhouse Cave), Turnhole Spring, McCoy Blue Spring, and Suds Spring (Figure 1, FWS 2007).

Portions of the Double Sink, Turnhole, McCoy Blue Spring, Suds Spring, Pike Spring, and Mile 205.7 Spring groundwater basins are located in oil fields where oil and natural gas wells are drilled (USFWS 1988). According to well data retrieved from the Kentucky Geological Survey (2008), hundreds of oil and gas wells occupy these areas. If not contained properly, brine from these wells can enter sinkholes or be washed into surface streams during storm flows. Drillers also sometimes pull out well casings, leading to intrusion into caves of oil, gas, and brine. Numerous, abandoned oil and gas wells in the region have been left open and have the potential to adversely affect groundwater basins. At present, the Kentucky Division of Oil and Gas Conservation, the state authority who grants permits in Kentucky, is not required under section 7 of the ESA to consult with the USFWS on potential impacts to listed species. Consequently, the Kentucky Ecological Services Field Office (KFO) does not review permits for areas surrounding MCNP that could impact cave shrimp basins.

Sediment (siltation) has been listed repeatedly by the Kentucky Division of Water as one of the most common stressors of aquatic communities in the Green River watershed (KDOW 2004; KDOW 2008) and agriculture was listed as the primary source of the siltation. These KDOW reports focus mainly on surface systems, but these same 8 pollutants undoubtedly affect groundwater systems that underlie this karst region. According to KDOW (2006), nonpoint-source impacts on groundwater in Kentucky are caused primarily by agriculturally related nutrients and pesticides. Pollutants of concern include nitrates (from fertilizer application, manure storage and application, and animal feeding operations), pesticides, and herbicides.

Threats occur from: traffic accidents; oil and gas operations; agricultural activities in which the primary concerns are sediment, nutrients and pesticides; stormwater runoff and septic system discharges in which the primary concern is bacteria; and impoundments in which the primary concern is sediment (NatureServe. 2014).

E. Freshwater Mussels

E.1 Cumberland elktoe

The Cumberland elktoe was listed as endangered on January 10, 1997 (62 FR 1647-1658). It exists in localized portions of the Cumberland River system in Kentucky and Tennessee. Presently, these species and their habitats are being impacted by deteriorated water quality, primarily resulting from poor land-use practices.

The Cumberland elktoe is known to exist in only three populations, two of which are in Kentucky. They persist in the middle section of Rock Creek, the upper portions of the Big South Fork Cumberland River basin and in Marsh Creek in McCreary County. Marsh Creek likely contains the best surviving elktoe population. This species appears to prefer habitats in medium-sized streams to large rivers that contain sand and mud substrata interspersed with cobbles and large boulders (Parmalee and Bogan 1998).

Any Cumberland elktoe populations that may have existed in the main stem of the Cumberland River were likely lost when Wolf Creek Dam was completed. Other tributary populations were likely lost due to the impacts of coal mining, pollution, and spills from oil wells. The upper Big South Fork basin population is threatened by coal mining runoff and could also be threatened by impoundments.

E.2 Spectaclecase

The Spectaclecase mussel was listed as endangered on March 13, 2012 (FR 77:14914). Adult mussels suspension feed, spending their entire lives partially or completely buried within the substrate (Murray and Leonard 1962, p. 27). Adults feed on algae, bacteria, detritus, microscopic animals, and dissolved organic material (Christian et al. 2004, pp. 108–109; Nichols and Garling 2000, p. 873; Silverman et al. 1997, p. 1859; Strayer et al. 2004, pp. 430–431). For their first several months, juvenile mussels employ foot (pedal) feeding, consuming bacteria, algae, and detritus (Yeager et al. 1994, p. 221).

Mussel biologists know relatively little about the specific life-history requirements of the Spectaclecase. The Spectaclecase life cycle includes a parasitic phase; however, despite extensive investigation, the host species is not yet known.

The decline of mussels such as the Spectaclecase is primarily the result of habitat loss and degradation (Neves 1991, pp. 252, 265). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, oil and gas development, and sedimentation (Neves 1991, pp. 252, 260–261; Neves 1993, pp. 1–7; Neves *et al.* 1997, pp. 63– 72; Strayer *et al.* 2004, pp. 435–437; Watters 2000, pp. 261–268).

Below dams, including those operated to generate hydroelectric power, mussel declines are associated with changes and fluctuation in flow regime, scouring and erosion, reduced dissolved oxygen levels and water temperatures, and changes in resident fish assemblages (Layzer *et al.* 1993, p. 69; Neves *et al.* 1997, pp. 63–64; Pringle *et al.* 2009, pp. 810–815; Watters 2000, pp. 265–266; Williams *et al.* 1992, p. 7).

Population losses due to impoundments have likely contributed more to the decline and imperilment of the Spectaclecase than any other factor. Large river habitat throughout nearly all of the range of the species has been impounded, leaving generally short, isolated patches of vestigial habitat in the area below dams. Navigational locks and dams, some high-wall dams and many lowhead dams have contributed significantly to the loss of Spectaclecase habitat.

Dam construction has a secondary effect of fragmenting the ranges of aquatic mollusk species, leaving relict habitats and populations isolated by the structures as well as by extensive areas of deep uninhabitable, impounded waters. These isolated populations are unable to naturally recolonize suitable habitat that is impacted by temporary, but devastating events, such as severe drought, chemical spills, or unauthorized discharges (77 FR 14936). Dams eliminate or reduce river flow within impounded areas, trap silts and cause sediment deposition, alter water temperature and dissolved oxygen levels, change downstream water flow and quality, decrease habitat heterogeneity, affect normal flood patterns, and block upstream and downstream movement of species (Layzer *et al.* 1993, pp. 68–69; Neves *et al.* 1997, pp. 63–64; Watters 2000, pp. 261–264).

Large river habitat throughout nearly all of the range of this species has been impounded, leaving generally short, isolated patches of remaining habitat in the area below dams. The majority of the Tennessee and Cumberland River main stems and many of their largest tributaries are now impounded. There are 36 major dams located in the Tennessee River system, and about 90 percent of the Cumberland River downstream of Cumberland Falls (RM 550 (RKM 886)) is either directly impounded by U.S. Army Corps of Engineers (Corps) structures or otherwise impacted by cold tail water released from several dams. Major Corps impoundments on Cumberland River tributaries have inundated an additional 100 miles (161 km) or more of Spectaclecase habitat.

Coldwater releases from Wolf Creek, Dale Hollow, and Center Hill Dams continue to degrade Spectaclecase habitat in the Cumberland River system. The scouring effects caused by 40 years of operation of the Center Hill Dam for hydroelectric power generation has dramatically altered the river morphology for 7 miles (12 km) downstream of the dam (Layzer *et al.* 1993, p. 69). Layzer *et al.* (1993, p. 68) reported that 37 of the 60 pre-impoundment mussel species of the Caney Fork River have been extirpated.

Watters (2000, pp. 262–263) summarizes the tremendous loss of mussel species from various portions of the Tennessee and Cumberland River systems.

A series of six locks and dams was constructed on the lower half of the Green River decades ago and extends upstream to the western boundary of Mammoth Cave National Park (MCNP). The upper two locks and dams destroyed Spectaclecase habitat, particularly Lock and Dam 6, which flooded the central and western portions of MCNP. Approximately 30 river miles (48 km) of mainstem habitat were also eliminated with the construction of the Green River Dam in 1969. Similarly, dams impound most of the upper Mississippi River and many of its tributaries. A series of 29 locks and dams constructed since the 1930s in the mainstem replaced a free-flowing alluvial (flood plain) system with a stepped gradient (higher pool area to riffle area ratio) river. Modifications fragmented the mussel beds where Spectaclecase were found in the Mississippi River, reduced stable riverine habitat, and disrupted fish host migration and habitat use.

Land use types around the Spectaclecase populations include pastures, row crops, timber, and urban and rural communities. Sedimentation has been implicated in the decline of mussel populations nationwide, and is a threat to Spectaclecase (Ellis 1936, pp. 39–40; Fraley and Ahlstedt 2000, pp. 193–194; Poole and Downing 2004, pp. 119–122; Vannote and Minshall 1982, pp. 4105–4106). Specific biological impacts include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, limited burrowing activity, physical smothering, and disrupted host fish attractant mechanisms (Ellis 1936, pp. 39–40; Hartfield and Hartfield 1996, p. 373; Marking and Bills 1979, p. 210; Vannote and Minshall 1982, pp. 4105– 4106; Waters 1995, pp. 173–175).

Agricultural activities produce the most significant amount of sediment that enters streams (including both sediment and chemical runoff) and affects 72 percent of the impaired river miles in the country (Waters 1995, pp. 17–18). Neves *et al.* (1997, p. 65). Unrestricted livestock access occurs on many streams and potentially threatens mussel populations (Fraley and Ahlstedt 2000, pp. 193–194). Grazing may reduce infiltration rates and increase runoff; trampling and vegetation removal increases the probability of erosion (Armour *et al.* 1991, pp. 8–10; Brim Box and Mosa 1999, p. 103). The majority of the remaining Spectaclecase populations are threatened by some form of agricultural runoff (nutrients, pesticides, sediment).

The Spectaclecase primarily inhabits deep water along the outside of bends and may be particularly vulnerable to siltation. The current often slackens in this habitat, more so than in riffles and runs where other mussel species are typically found, and suspended sediment settles out.

Channel maintenance operations for commercial navigation have impacted habitat for the Spectaclecase in many large rivers range-wide. Continual maintenance of the Mississippi River navigation channel requires dredging; wing and closing dam reconstruction and maintenance; and bank armoring. Dredging, maintenance, and construction activities destabilize instream fine sediments and continue to affect aquatic habitats

E.3 Fanshell

The Fanshell mussel was listed as endangered[12] on June 21, 1990. A recovery plan addressing the Fanshell was approved in July 9, 1991 (USFWS 1991). This freshwater mussel is characterized as a medium to large river species (Bates and Dennis 1985).

This mussel feeds by filtering food particles including disintegrated organic debris, algae, diatoms and bacteria from the water. The diet of fanshell glochidia, like other freshwater mussels, comprises water (until encysted on a fish host) and fish body fluids (once encysted).

The reproductive cycle of the fanshell is similar to that of other native freshwater mussels. Males release sperm into the water column; the sperm are then taken in by the females through their siphons during feeding and respiration. The females retain the fertilized eggs in their gills until the larvae (glochidia) fully develop. The mussel glochidia are released into the water, and within a few days they must attach to the appropriate species of fish, which they parasitize for a short time while they develop into juvenile mussels. The species is a long-term brooder and holds glochidia overwinter for a spring release (Ortmann 1919). Fanshell glochidia are released in the form of a unique spiral worm-like conglutinate suggesting that this species relies on fish hosts that visually search for food (USFWS 1991). Recent induced infestations of glochidia on nine of sixteen fish species tested indicate that the following species are suitable hosts: mottled sculpin (*Cottus bairdi*), banded sculpin (*Cottus carolinae*), greenside darter (*Etheostoma blennioides*), snubnose darter (*Etheostoma simoterum*), banded darter (*Etheostoma zonale*), tangerine darter (*Percina aurantiaca*), blotchside logperch (*Percina burtoni*), logperch (*Percina caprodes*), and Roanoke darter (*Percina roanoka*) (Jones and Neves 2000).

The fanshell has undergone a substantial range reduction. It was historically distributed in the Ohio, Wabash, Cumberland, And Tennessee Rivers and their larger tributaries in Pennsylvania, Ohio, West Virginia, Illinois, Indiana, Kentucky, Tennessee, Alabama, and Virginia (Johnson 1980, KSNPC 1980, Ahlstedt 1986, Bates and Dennis 1985, Cummings et al. 1987 and 1988, Starnes and Bogan 1988, USFWS 1991). It is believed that reproducing populations are now present in only three rivers, the Clinch River (Hancock County, TN and Scott County, VA), the Green River (Hart and Edmonson Counties, KY), and the Licking River (Kenton, Campbell, and Pendleton Counties, KY). In addition, based on collections of a few older individuals in the 1980s, small remnant (apparently non-reproducing) populations may still persist in the Muskingum River (Morgan and Washington Counties, OH), the Walhonding River (Coshocton County, OH), the Wabash River (White County, IL and Posey and Wabash Counties, IN), the East Fork White River (Martin County, IN), the Tippecanoe River (Tippecanoe County, IN), the Kanawha River (Fayette County, WV), Tygarts Creek (Greenup and Carter Counties, KY), the Barren River (Allen and Barren Counties, KY), the Cumberland River (Smith County, TN), and the Tennessee River (Rhea, Meigs, and Hardin County, TN) (USFWS 1990,1991).

The loss of many historic populations was likely due to the impacts of impoundments, navigation projects, water quality degradation, and other forms of habitat alteration, including gravel and sand dredging that directly affected the species and reduced or eliminated its fish host (USFWS 1991). The Green River population of the species, though afforded some protected habitat in

[12] http://ecos.fws.gov/docs/federal_register/fr1716.pdf, as viewed on 10/28/2014

Mammoth Cave National Park, has been threatened by runoff from oil and gas exploration and production sites and by stream flow alteration from an upstream reservoir (USFWS 1990, 1991).

A reproducing population of the Fanshell in the Licking River is supported only in the lower portion of the drainage (USFWS 1990, 1991). In the Licking River, live and fresh-dead individuals of several year classes have been collected (USFWS 2003). The Licking River population of the Fanshell has been threatened by the effects of wastewater discharges and plans for water supply development. Incidental take of the Fanshell where it is co-located with commercially harvested mussel beds is also attributed to its decline (USFWS 1990, 1991). Most Fanshell populations are small and are geographically isolated from one another. It is likely that many of the remaining populations are now small enough that they can no longer maintain long-term genetic viability (Soule 1980).

E.4 Dromedary pearlymussel

This species was listed as federally endangered in the U.S. on June 14, 1976 and a recovery plan was created (USFWS, 1984). The states in which this population is known to or is believed to occur are Alabama and Tennessee. This species is possibly extirpated from Kentucky (has not been observed in Kentucky for over 20 years). It was once common throughout the Tennessee River system. It is currently known from the middle Cumberland River in Smith County, Tennessee; the Tennessee River in Meigs County, Tennessee; and in the upper Powell and Clinch rivers in Tennessee and Virginia (Parmalee and Bogan, 1998; Jones et al., 2004). In Alabama, it historically occurred in the Tennessee River downstream of Muscle Shoals but has not been reported in Alabama since the 1930s, thus it is likely extirpated; but current reintroduction efforts are underway (Mirarchi et al., 2004).

Formerly widespread throughout the Cumberland and Tennessee River systems in Tennessee, Alabama, and Virginia, this species has become extremely rare throughout its present range with only three (possibly two) viable populations remaining. The species is declining at all extant sites because of habitat degradation and population sizes below viability levels. Reproducing populations occur only in the upper Clinch and Powell Rivers in Tennessee and Virginia above Norris Reservoir (Jones et al., 2004).

Adult freshwater mussels are largely sedentary spending their entire lives very near to the place where they first successfully settled (Coker et al., 1921; Watters, 1992). Movement occurs with the impetus of some stimulus (nearby water disturbance, physical removal from the water such as during collection, exposure conditions during low water, seasonal temperature change or associated diurnal cycles) and during spawning. Movement is confined to either vertical movement burrowing deeper into sediments though rarely completely beneath the surface, or horizontal movement in a distinct path often away from the area of stimulus. Vertical movement is generally seasonal with rapid descent into the sediment in autumn and gradual reappearance at the surface during spring (Amyot and Downing, 1991; 1997). Horizontal movement is generally on the order of a few meters at most and is associated with day length and times of spawning (Amyot and Downing, 1997). Such locomotion plays little, if any, part in the distribution of freshwater mussels as these limited movements are not dispersal mechanisms.

Threats include impoundments, siltation and pollution leading to water quality and habitat deterioration, inadequate sewage treatment, coal mining, oil and gas drilling and poor land-use practices. USFWS (1984) cites alteration and destruction of stream habitat due to impoundment of the Tennessee and Cumberland Rivers and tributaries for flood control, navigation, hydroelectric power production, and recreation as the single greatest factor contributing to this species' decline. A second factor that has severely affected this species is siltation. This is especially evident with this species as it requires clean, flowing water over stable, silt-free rubble, gravel, and sand shoals to prevent smothering. Also coal production in the Appalachian region has increased in the last few decades; which results in increased silt runoff. A third factor, although on a much broader scale, is the impact caused by various pollutants. Evidence of pollution and associated mussel disappearance in these areas dates back to Ortmann (1918).

E.5 Cumberlandian combshell

The Cumberlandian combshell was listed as endangered, nonessential experimental population on January 10, 1997. Historically, this species was distributed throughout the Cumberlandian region of the Tennessee and Cumberland River systems in Alabama, Kentucky, Mississippi, Tennessee, and Virginia (USFWS, 2003; 2004). Little else is known ecologically of this species other than it formerly was fairly common throughout its geographic range.

The Cumberlandian combshell have undergone significant reductions in range and numbers. They now exist as relatively small, isolated populations. The Cumberlandian combshell exists in localized portions of the Cumberland River system in Kentucky and Tennessee. This species and its habitat are being impacted by deteriorated water quality, primarily resulting from poor land-use practices. Because this species has such restricted ranges, it is vulnerable to toxic chemical spills.

Populations are currently known from Buck Creek in Kentucky, through a few miles of the Big South Fork Cumberland River in Kentucky and Tennessee and in very low numbers in the Powell and Clinch Rivers in Virginia and Tennessee (USFWS, 1997). Currently, it is restricted to five stream reaches (USFWS, 2003; 2004). It has been extirpated from a large percentage of its former range (likely over 80%). Tennessee Valley Authority (TVA) data indicates that populations continue to decline (USFWS, 2003; 2004). It has been eliminated from the mainstem of the Tennessee and Cumberland Rivers and several tributaries. Current populations occur in Buck Creek (Pulaski County, Kentucky), Big South Fork Cumberland River (Scott County, Tennessee and McCreary County, Kentucky) (USFWS, 2003; 2004). The present populations are threatened by the adverse impacts of coal mining, poor land-use practices, and pollution, primarily from nonpoint source pollution.

The greatest threat to this species in the Cumberlandian Region is habitat alteration. Principal causes include impoundments, channelization, pollution, and sedimentation that have altered or eliminated those habitats that are essential to the long-term viability of many riverine mussel populations. Impoundments result in the elimination of riffle and shoal habitats, disruption of a river's ecological processes, elimination of current and the covering of rock and sand substrates by fine sediments, and alteration of downstream water quality and riverine habitat. Daily discharge fluctuations, bank sloughing, seasonal oxygen deficiencies, cold-water releases, turbulence, high silt loads, and altered host fish distribution have contributed to limited mussel recruitment and skewed demographics. Impoundments, as barriers to dispersal, contribute to the loss of local populations by blocking post extirpation recolonization. Population losses due to impoundments have probably contributed more to the decline of the Cumberlandian combshell, and most other Cumberlandian Region mussels than any other single factor.

The entire length of the Tennessee River and much of the Cumberland River is maintained as a navigation channel with a series of locks and dams--nine on the Tennessee River and four on the Cumberland River. Channel maintenance activities continue to cause substrate instability and alteration in these rivers and may serve to diminish what habitat remains for the recovery of riverine species.

Heavy metal-rich drainage from coal mining and associated sedimentation have adversely impacted many stream reaches, destroying mussel beds and preventing natural recolonization. Impacts associated with coal mining activities have particularly altered upper Cumberland River system streams with diverse historical mussel faunas and have been implicated in the decline of *Epioblasma* species, especially in the Big South Fork. Strip mining continues to threaten mussels in coal field drainages of the Cumberland Plateau with increased sedimentation loads and acid mine drainage, including Cumberlandian combshell populations.

In-stream gravel mining has been implicated in the destruction of mussel populations. Negative impacts include riparian forest clearing (e.g., mine site establishment, access roads, lowered floodplain water table); stream channel modifications (e.g., geomorphic instability, altered habitat, disrupted flow patterns [including lowered elevation of stream flow], sediment transport); water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature); macroinvertebrate population changes (e.g., elimination, habitat disruption, increased sedimentation); and changes in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions). Gravel mining activities threaten the Cumberlandian combshell populations in the Powell River and in Buck Creek, the latter stream representing one of only two remaining populations of this species in the entire Cumberland River system.

Agricultural sources of chemical contaminants are considerable and include two broad categories--nutrients and pesticides. Nutrient enrichment generally occurs as a result of runoff from livestock farms and feedlots and from fertilizers used on row crops. Pesticide runoff that commonly ends up in streams may have effects on the combshell. Numerous Cumberlandian Region streams have experienced mussel kills from toxic chemical spills and other causes.

Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering. Host fish/mussel interactions may be indirectly impacted by changes in stream sediment regimes through three mechanisms: reduction of fish abundance, diversity, and reproduction; hindering host fish attractant mechanisms; and interference with the ability of some species' adhesive conglutinates to adhere to rock particles.

Waterborne sediment is produced by the erosion of stream banks, channels, plowed fields, unpaved roads, roadside ditches, upland gullies, and other soil disturbance sites. Agricultural activities produce the most significant amount of sediment that enters streams. Silvicultural sedimentation impacts are more the result of logging roads than the actual harvesting of timber.

Developmental activities associated with urbanization (e.g., highways, building construction, infrastructure creation, recreational facilities) may contribute significant amounts of sediment and other pollutants in quantities that may be detrimental to stream habitats. With development, watersheds become more impervious, resulting in increased storm-water runoff into streams and a doubling in annual flow rates in completely urbanized streams. Impervious surfaces may reduce sediment input into streams but result in channel instability by accelerating storm-water runoff, which increases bank erosion and bed scouring. Water withdrawals for agricultural irrigation and municipal and industrial water supplies are an increasing concern for all aquatic resources and are directly correlated with expanding human populations (NatureServe 2014).

E.6 Oyster mussel

The Oyster mussel was listed as Endangered on January 10, 1997 (62 FR 1647-1659). It is listed as endangered throughout its range, except in the free-flowing reach of the Tennessee River from the base of Wilson Dam downstream to the backwaters of Pickwick Reservoir and the lower 5 river miles of all tributaries to this reach in Colbert and Lauderdale Counties, Alabama. Here it is listed as an experimental, non-essential population (Federal Register, 14 June 2001).

This species is somewhat sessile with only limited movement in the substrate. Passive downstream movement may occur when mussels are displaced from the substrate during floods. Major dispersal occurs while glochidia are encysted on their hosts (NatureServe, 2014).

Oyster mussels have undergone significant reductions in range and numbers. They now exist as relatively small, isolated populations. The oyster mussel persists at extremely low numbers in portions of the Cumberland and Tennessee River basins in Kentucky, Tennessee, and Virginia. Presently, these species and their habitats are being impacted by deteriorated water quality, primarily resulting from poor land-use practices.

The greatest threat to this species in the Cumberlandian Region is habitat alteration. Principal causes include impoundments, channelization, pollution, and sedimentation that have altered or eliminated those habitats that are essential to the long-term viability of many riverine mussel populations. Impoundments result in the elimination of riffle and shoal habitats, disruption of a river's ecological processes (flooding, loss of bottom stability, bank sloughing), elimination of current and the covering of rocky and sand substrates by fine sediments, and alteration of downstream water quality and riverine habitat. Daily discharge fluctuations, bank sloughing, seasonal oxygen deficiencies, cold-water releases, turbulence, high silt loads, and altered host fish distribution have contributed to limited mussel recruitment and skewed demographics. Impoundments, as barriers to dispersal, contribute to the loss of local populations by blocking post-extirpation recolonization. Population losses due to impoundments have probably contributed more to the decline of the Oyster mussel than any other single factor (USFWS, 2004).

Dredging and channelization activities have profoundly altered riverine habitats nationwide, with effects on streams. Channel construction for navigation has been shown to increase flood heights thus exacerbating flood events that convey to streams large quantities of sediment with adsorbed contaminants; and channel maintenance may also result in downstream impacts. The entire length of the Tennessee River and much of the Cumberland River is maintained as a navigation channel with a series of locks and dams--nine on the Tennessee River and four on the Cumberland River. Channel maintenance activities continue to cause substrate instability and alteration in these rivers and may serve to diminish what habitat remains for the recovery of riverine species (USFWS, 2004).

This species has declined (> 80%) to a few disjunct occurrences from what was a much more widespread historic distribution. Populations are discontinuous in nine tributaries and it is rare at these localities with evidence of decline. One population is threatened by dam construction. There is potential for discovery of new populations (NatureServe 2014).

This species survives as a very rare component of the benthic community of Buck Creek, Big South Fork of the Cumberland River in Kentucky. Much of the oyster mussel's historic range has been impounded. Other populations were lost due to various forms of pollution and siltation. The present populations are threatened by the adverse impacts of coal mining, poor land-use practices, and pollution, primarily from nonpoint pollution. All the known populations are small and could be decimated by naturally occurring events such as toxic chemical spills.

Most of the main stem of both the Tennessee and Cumberland rivers and many of their tributaries are impounded. In addition to the loss of riverine habitat within impoundments, most impoundments also seriously alter downstream aquatic habitat; and mussel populations upstream of reservoirs may be adversely affected by changes in the fish fauna essential to a mussel's reproductive cycle.

Historically, this species was distributed throughout the Cumberlandian region of the Tennessee and Cumberland River drainages in Alabama, Georgia, Kentucky, North Carolina, Tennessee, and Virginia in 82 localities (USFWS, 2003; 2004). Currently, in the Cumberland River drainage, remnant populations are found in Buck Creek and the Big South Fork Cumberland River in Kentucky and Tennessee.

Population size is difficult to estimate, but TVA qualitative surveys and quantitative estimates of density have been very low and continue to decline. Barr et al. (1994) determined (based on 1981 survey data) that viable populations exist in the Big South Fork (Scott County, Tennessee and McCreary County, Kentucky) (USFWS, 2003; 2004).

Heavy metal-rich drainage from coal mining and associated sedimentation have adversely impacted many stream reaches, destroying mussel beds and preventing natural recolonization. Impacts associated with coal mining activities have particularly altered upper Cumberland River system streams with diverse historical mussel faunas and have been implicated in the decline of *Epioblasma* species, especially in the Big South Fork. Strip mining continues to threaten mussels in coal field drainages of the Cumberland Plateau with increased sedimentation loads and acid mine drainage.

In-stream gravel mining has been implicated in the destruction of mussel populations. Negative impacts include riparian forest clearing (e.g., mine site establishment, access roads, lowered floodplain water table); stream channel modifications (e.g., geomorphic instability, altered habitat, disrupted flow patterns [including lowered elevation of stream flow], sediment transport); water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature); macroinvertebrate population changes (e.g., elimination, habitat disruption, increased sedimentation); and changes in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions).

Contaminants contained in point and nonpoint discharges can degrade water and substrate quality and adversely impact, if not destroy, mussel populations. Although chemical spills and other point sources (e.g., ditch, swale, artificial channel, drainage pipe) of contaminants may directly result in mussel mortality, widespread decreases in density and diversity may result, in part, from the subtle, pervasive effects of chronic low-level contamination. Mussels appear to be among the most intolerant organisms to heavy metals, several of which are lethal, even at relatively low levels (NatureServe 2014).

Agricultural sources of chemical contaminants are considerable and include two broad categories--nutrients and pesticides. Nutrient enrichment generally occurs as a result of runoff from livestock farms and feedlots and from fertilizers used on row crops. Pesticides, primarily from row crops, are a major source of agricultural contaminants. Pesticide runoff that commonly ends up in streams may have effects (based on studies with laboratory-tested mussels) that are particularly profound (NatureServe 2014).

This species was once a commonly found species (1970's), but abundance has dropped and it has been extirpated from many former sites including the mainstems of the Cumberland and Tennessee Rivers now only extant in a handful of stream and river reaches in four states in the Tennessee and Cumberland River systems (USFWS 2003; 2004). This represents an approximate 80% reduction in range.

E.7 Tan riffleshell

The Tan riffleshell was listed as Endangered on January 2, 1993. This species is known from the Cumberland and Tennessee River systems. In Kentucky, Cicerello and Schuster (2003) list it as sporadic in the upper Cumberland River below Cumberland Falls. A population also exists in the Big South Fork Cumberland River, Tennessee and Kentucky. The Big South Fork Cumberland River populations in Tennessee and Kentucky are uncommon but reproducing. The status of the remaining populations is presently unknown due to the rarity of the mussel (Neves, 1991).

Most of the main stem of both the Tennessee and Cumberland rivers and many of their tributaries are impounded. In addition to the loss of riverine habitat within impoundments, most impoundments also seriously alter downstream aquatic habitat; and mussel populations upstream of reservoirs may be adversely affected by changes in the fish fauna essential to a mussel's reproductive cycle.

This species survives as a very rare component of the benthic community of Buck Creek, Big South Fork of the Cumberland River in Kentucky. Other populations were lost due to various forms of pollution and siltation. The present populations are threatened by the adverse impacts of coal mining, poor land-use practices, and pollution, primarily from nonpoint pollution.

Coal mining-related siltation and associated toxic runoff have adversely impacted many stream reaches. Numerous streams have experienced mussel and fish kills from toxic chemical spills, and poor land-use practices have fouled many waters with silt. Runoff from large urban areas has degraded water and substrate quality. Because of the extent of habitat destruction, the overall aquatic faunal diversity in many of the basins' rivers has declined significantly (NatureServe). http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=F00X, as viewed 10/28/2014 http://ecos.fws.gov/docs/federal_register/fr3032.pdf, as viewed 10/28/2014

E.8 Catspaw

This subspecies was listed as federally endangered in the U.S. in 1990 and a recovery plan created (USFWS, 1990d). Presently, catspaw is known from two relic, apparently non-reproducing, populations--one in Tennessee and one in Kentucky. Historically, the subspecies occurred in the Ohio River and its larger tributaries in Ohio, Indiana, Illinois, Kentucky, Tennessee, and Alabama. It inhabits large river systems in sand and gravel substrates in runs and riffles. The specific food habits of the catspaw are unknown, but it likely feeds on food items similar to those consumed by other freshwater mussels. Freshwater mussels are known to feed on detritus, diatoms, phytoplankton, and zooplankton (Churchill and Lewis 1924).

Cicerello and Schuster (2003) cite Kentucky distribution as formerly in the Ohio River and Green River to the Licking River. Now reproducing populations only exist in the Killbuck Creek, Ohio, the Cumberland River in Tennessee, and the Green River in Kentucky (USFWS, 1990). *E. obliquata* once occurred in the Scioto River in Ohio; in the Lower Ohio River (Goodrich and van der Schalie, 1944) and its Kentucky tributaries of the Licking, Green, and Kentucky Rivers (Johnson, 1978); and the Cumberland River proper in Kentucky (Johnson, 1978). It is apparently extirpated from Ohio, Alabama (Mirarchi et al., 2004), and Indiana and is now known only from Kentucky and Tennessee. Three extant populations of the *Epioblasma obliquata* are thought to exist; one in the Green River in Kentucky, Cumberland River in Tennessee, and Killbuck Creek in Ohio (Isom et al., 1979; Hoggarth et al., 1995; Parmalee and Bogan, 1998; Watters et al., 2009).

The subspecies' reproductive biology remains virtually unknown, but it likely reproduces like other freshwater mussels. Males release sperm into the water column, which are taken in by the females through their siphons during feeding and respiration. The fertilized eggs are retained in the females' gills until the larvae (glochidia) fully develop. The glochidia are released into the water where they attach and encyst on the gills or fins of a fish host. When metamorphosis is complete, they drop to the streambed as juvenile mussels. The fish hosts utilized by the catspaw and the habitat of the juvenile mussel are unknown.

Pollution through point (industrial and residential discharge) and non-point (siltation, herbicide and fertilizer run-off) sources is perhaps the greatest on-going threat to this species and most freshwater mussels. Lowered dissolved oxygen content and elevated ammonia levels (frequently associated with agricultural runoff and sewage discharge) have been shown to be lethal to some species of freshwater naiads (Horne and McIntosh, 1979). Residential, mineral and industrial development also pose a significant threat. Rotenone, a toxin used to kill fish in bodies of water for increased sport fishery quality, has been shown to be lethal to mussels as well (Heard, 1970). Destruction of habitat through stream channelization and maintenance and the construction of dams is still a threat in some areas. Impoundments reduce currents that are necessary for basic physiological activities such as feeding, waste removal and reproduction. In addition, reduced water flow typically results in a reduction in water oxygen levels and a settling out of suspended solids (silt, etc.), both of which are detrimental. Dredging of streams has an immediate effect on existing populations by physically removing and destroying individuals. Dredging also affects the long-term recolonization abilities by destroying much of the potential habitat, making the substrates and flow rates uniform throughout the system. Natural predators include raccoons, otter, mink, muskrats, turtles and some birds (Simpson, 1899; Boepple and Coker, 1912; Evermann and Clark, 1918; Coker et al., 1921; Parmalee, 1967; Snyder and Snyder, 1969). Domestic animals such as hogs can root mussel beds to pieces (Meek and Clark, 1912). Fishes, particularly catfish, *Ictalurus* spp. and *Ameirus* spp.., and freshwater drum, *Aplodinotus grunniens*, also consume large numbers of unionids.

USFWS (1990; 1992) summarizes the major threats to the subspecies. Many historic populations were eliminated when river sections they inhabited were impounded (similarly affected host fish). The Green River in Kentucky has experienced water quality problems related to impacts from oil and gas production in the watershed, and commercial mussel fishing has occurred in the watershed in recent years past. Individuals still surviving in the Cumberland River watershed are potentially threatened by gravel dredging, channel maintenance, and commercial mussel fishing (recent past only- incidental take).

E.9 Northern riffleshell

On January 22, 1993, the Northern riffleshell was designated by the USFWS as endangered (USFWS, 1993: 58 FR 5638-5642). The species is also considered as endangered by the freshwater mussel subcommittee of the endangered species committee of the American Fisheries Society (Williams et al., 1993). A recovery plan addressing the Northern riffleshell was approved by the USFWS on September 21, 1994 (USFWS, 1994).

The Northern riffleshell is approximately 3 inches in length; the shell’s exterior surface is brownish to yellowish-green with fine green rays. The inside of the shell is usually white, but can be pink (Stansbery et al., 1982). Ortmann (1919: 334) reported that this species was "always found...on riffles, on a bottom of firmly packed and rather fine gravel, in swiftly flowing, shallow water or coarse gravel" and Clarke (1981: 362) gave its habitat as "highly oxygenated riffle." Its preferred habitat appears to require swiftly moving water. The high oxygen concentrations in swift streams may be necessary for survival. It is a species of riffle areas of smaller streams, and as such has fared better than larger river species, which have been heavily impacted by dredging and impoundment. Of the eleven or so species of naiads thought to be extinct in 1971 by Stansbery, most were from this latter type of habitat and all were species of *Epioblasma.*

Historically, the riffleshell occurred throughout much of the Ohio River watershed; however, the range has been dramatically reduced to eight to ten populations scattered over four states and one province with only three that are considered viable. Currently the Northern riffleshell is extant in only seven streams; the Green River in Kentucky, French and LeBoeuf Creeks and the Allegheny River in Pennsylvania, the Detroit River in Michigan (possibly extirpated), and Big Darby Creek in Ohio (USFWS, 1993), and recently discovered in at least one additional river in Ontario (Metcalfe-Smith et al., 1998). This species now exists in eight to ten isolated populations, most of which are small and peripheral and with little signs of reproduction. It is known from the Kentucky, Licking, and Green River drainages in Kentucky (Johnson, 1978), but is likely only still extant in the Upper Green. It historically occurred in the Ohio River in several places including the Smithland dam pool in Illinois, Meldahl dam pool in Ohio/Kentucky, and as far as the Upper Ohio just into Pennsylvania (Watters and Flaute, 2010). Taylor and Hughart (1981) presumed that it was no longer present in the Elk River of West Virginia. *Epioblasma torulosa rangiana* has experienced greater than a 95% range reduction (USFWS, 1993; 1994; Staton et al., 2000).

Impoundment of the Clinch River in Tennessee by the Norris Reservoir has resulted in the extirpation of the majority of species below the dam (Ahlstedt, 1984). The construction of the Wilson Dam on the Tennessee River has eliminated 20 of the original 22 Cumberlandian naiad species (Stansbery, 1971). Smith (1971) ranked the causes of extirpation or declines in fish species as follows: siltation, drainage of bottomland lakes, swamps, and prairie marshes, desiccation during drought, species introductions, pollution, impoundments, and increased water temperatures. All of these factors render habitats unsuitable, cause extirpations, and lead to the isolation of populations thereby increasing their vulnerability to extirpation for many aquatic species (including mussels) throughout North America. Pollution through point (industrial and residential discharge) and non-point (siltation, herbicide and fertilizer run-off) sources is perhaps the greatest on-going threat to this species and most freshwater mussels. Destruction of habitat through stream channelization and maintenance and the construction of dams although slowed in recent years is still a threat in some areas. Impoundments reduce currents that are necessary for the most basic physiological activities such as feeding, waste removal and reproduction. In addition, reduced water flow typically results in a reduction in water oxygen levels and a settling out of suspended solids (silt, etc.), both of which are detrimental. Dredging of streams has an immediate effect on existing populations by physically removing and destroying individuals. Dredging also affects the long-term recolonization abilities by destroying much of the potential habitat, making the substrates and flow rates uniform throughout the system. Rotenone, a toxin used to kill fish in bodies of water for increased sport fishery quality, has been shown to be lethal to mussels as well (Heard, 1970). Natural predators include raccoons, otter, mink, muskrats, turtles and some birds, which feed heavily upon freshwater mussels (Simpson, 1899; Boepple and Coker, 1912; Evermann and Clark, 1918; Coker, et al. 1921; Parmalee, 1967; Snyder and Snyder, 1969). Domestic animals such as hogs can root mussel beds to pieces (Meek and Clark, 1912). Fishes, particularly catfish, *Ictalurus* spp. and *Amierus* spp. and freshwater drum, *Aplodinotus grunniens* also consume large numbers of unionids. USFWS (1994) lists the following reasons for decline: siltation (from agriculture, construction, and forestry runoff), impoundment (including dam construction and maintenance), instream sand and gravel mining (for channelization), pollutants (pesticides and fertilizers, heavy metals, ammonia from wastewater, acid-mine runoff, and invasive species (zebra mussel, quagga mussel).

This freshwater mussel occurs in a wide variety of large and small streams, preferring riffles and runs with bottoms composed of firmly packed sand and fine to coarse gravel (Watters, 1990). Preferred habitat appears to require flowing water in mid-size rivers. High dissolved oxygen concentrations in streams may be necessary for survival. No critical habitat has been designated for the riffleshell.

Riffleshells appear to have a relatively short life-span for a freshwater mussel. Sexual maturity can be reached in as little as three years, and most individuals probably live for only eight to 15 years (Rodgers et al., 2001). Most mussels probably experience very low annual juvenile survival. The combination of short life span and low fecundity indicates that populations depend on a large annual cohort resulting from a large population (Musick, 1999). Species following this reproductive strategy are susceptible to loss of individuals from predation and stochastic events, and are slow to recover from such losses (Rodgers et al., 2001), but may be well suited to exploit dynamic micro-habitat shifts characteristic of free-flowing rivers.

The primary factors that can be attributed to the reduction in riffleshell's range include impoundments, channelization, loss of riparian habitat, and the impacts of silt from poor land use (USFWS, 1995). Water pollution from municipalities, chemical discharges, coal mines, and reservoir releases have also impacted the species.

E.10 Snuffbox

The snuffbox was listed as endangered on February 14, 2012. It is a triangular-shaped freshwater mussel; relatively thick for its size, yellow or yellowish green with green rays, blotches, or chevron markings. The snuffbox is found in small- to medium-sized creeks, to larger rivers, and in lakes (Cummings and Mayer 1992, p. 162; Parmalee and Bogan 1998, p. 108). The species occurs in swift currents of riffles and shoals and wave washed shores of lakes over gravel and sand with occasional cobble and boulders. Individuals generally burrow deep into the substrate, except when spawning or attempting to attract a host (Parmalee and Bogan 1998, p. 108). Strayer (1999a, pp. 471–472) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that display little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives. Strayer thought that features commonly used in the past to explain the spatial patchiness of mussels (water depth, current speed, sediment grain size) were poor predictors of where mussels actually occur in streams.

Extant populations of the snuffbox are known in the following Kentucky waters: Tygarts Creek, Kinniconick Creek, Licking River, Slate Creek, Middle Fork Kentucky River, Red Bird River, Red River, Rolling Fork Salt River, Green River, and Buck Creek. All these have population status categories of "marginal" except for the Red River which has a "significant" population status category listing.

The snuffbox has been eliminated from about 62 percent of the streams in which it historically occurred. Furthermore, extant populations, with few exceptions, are highly fragmented and restricted to short reaches. Available records indicate that 32 percent of streams considered to harbor extant populations of the snuffbox are represented by only one or two individuals. The primary cause of range curtailment for the Snuffbox has been modification and destruction of river and stream habitats, primarily by the construction of impoundments.

The reproductive process of riverine mussels is generally disrupted by impoundments, making the snuffbox unable to successfully reproduce and recruit under reservoir conditions. Population losses due to impoundments have likely contributed more to the decline and imperilment of the snuffbox than has any other single factor. This species does not occur in reservoirs lacking riverine characteristics, although persists in some reaches of large rivers with dams (Ohio River and Allegheny River). It is restricted to sections retaining riverine characteristics (generally tailwaters).

Stream habitat throughout major portions of the range of this species has been impounded. The majority of the Tennessee and Cumberland River mainstems and many of their largest tributaries are now impounded. There are 36 major dams located in the Tennessee River system, and about 90 percent of the Cumberland River downstream of Cumberland Falls is either directly impounded by U.S. Army Corps of Engineers (Corps) structures or otherwise impacted by cold tailwater released from dams. Watters (2000, pp. 262–263) summarizes the tremendous loss of mussel species from various portions of the Tennessee and Cumberland River systems. The snuffbox, once widespread throughout both systems, now persists in only five Tennessee River tributaries and one Cumberland River tributary.

Mussel biologists know relatively little about the specific life-history requirements of the snuffbox. This species is declining throughout its widespread range and has become increasingly rare, although several dozen occurrences remain; many of them with good viability. Distribution is greatly fragmented but remains relatively wide. Long-term viability of most populations is questionable especially those in large rivers where zebra mussel populations are now established.

It was historically widespread in the upper Mississippi and Ohio River drainages. It was widespread but never abundant in the Tennessee River system. It has been drastically reduced in range and is endangered in many states where it occurs. Extant populations can still be found in Wisconsin, Illinois, Indiana, Kentucky, Michigan, Ohio, Pennsylvania, Tennessee, and West Virginia. Most populations are small and geographically isolated from one another. In Mississippi, it is found only in Tennessee River drainage (Jones et al., 2005). In Kentucky, it is sporadic in the upper Green River and eastward (Cicerello and Schuster, 2003).

Residential, mineral and industrial development also pose a significant threat. Rotenone, a toxin used to kill fish in bodies of water for increased sport fishery quality, has been shown to be lethal to mussels as well (Heard, 1970). Destruction of habitat through stream channelization and maintenance and the construction of dams is still a threat in some areas. Impoundments reduce currents that are necessary for basic physiological activities such as feeding, waste removal and reproduction. In addition, reduced water flow typically results in a reduction in water oxygen levels and a settling out of suspended solids (silt, etc.), both of which are detrimental. Dredging of streams has an immediate effect on existing populations by physically removing and destroying individuals. Dredging also affects the long-term recolonization abilities by destroying much of the potential habitat, making the substrates and flow rates uniform throughout the system. Natural predators include raccoons, otter, mink, muskrats, turtles and some birds (Simpson, 1899; Boepple and Coker, 1912; Evermann and Clark, 1918; Coker et al., 1921; Parmalee, 1967; Snyder and Snyder, 1969). Domestic animals such as hogs can root mussel beds to pieces (Meek and Clark, 1912). Fishes, particularly catfish, *Ictalurus* spp. and *Ameirus* spp. and freshwater drum, *Aplodinotus grunniens*, also consume large numbers of unionids

E.11 Cracking pearlymussel

This species was listed as federally endangered in the U.S. in 1989 and a recovery plan created (USFWS, 1990). This species has been severely reduced through habitat degradation in range to only three widely disjunct populations on two rivers, one of which may no longer be viable; and all of which are represented by a small number of individuals. Impoundments, siltation and pollution leading to water quality and habitat deterioration. Inadequate sewage treatment, coal mining, oil and gas drilling and poor land-use practices. The Powell River watershed was mined extensively for coal, and coal mining impacts are still present, especially in the upper reaches. The lower reaches of the Powell River have large deposits of coal fines and silt. The cracking pearlymussel populations in the Powell River and Clinch River are likely declining due to sedimentation (i.e., coal fines) (USFWS 2011). Although suitable habitat exists in the Elk River, cold water releases from Tims Ford Reservoir and pollution from unknown sources in the lower Elk River have impacted mussel fauna and reduced density (USFWS, 1990). It has been extirpated from most of its former range but some viable populations may persist in the upper Clinch River in Hancock Co., Tennessee (Parmalee and Bogan, 1998), and Scott Co., Virginia; as well as the Elk River in Lincoln Co., Tennessee (USFWS, 1990). Major threats to the species and its habitat include coal mining (siltation and fines), oil and gas exploration, highway and bridge construction, municipal and industrial discharges, and residential, industrial, and commercial development (USFWS August 2011).

E.12 Pink mucket

This species was listed as federally endangered in the U.S. in 1976 and a recovery plan (USFWS, 1985) was drafted. The overall range of this once very widespread species has diminished, but this species was always considered rare whenever it was found and it seems to be surviving and reproducing in sections of river that have been altered by impoundments. More dramatic has been the decline in area of occupancy (probably greater than 30%) as it continues to be found in historical sites but often only in very low numbers. Although currently known from a few dozen localities, most are represented by very few individuals and have poor viability. If populations west of the Mississippi River prove to be a different species the conservation status will need to be reevaluated.

Characterized as a large river species (Dennis, 1984) associated with fast-flowing waters, although in recent years it has been able to survive and reproduce in impoundments with river-lake conditions but never in standing pools of water (USFWS, 1985). Found in waters with strong currents, rocky or boulder substrates, with depths up to about 1 m, but is also found in deeper waters with slower currents and sand and gravel substrates (Gordon and Layzer, 1989; USFWS, 1985). Despite extensive declines historically, the species appears to have adapted somewhat to existence in impounded sections of big rivers. Rarer occurrence of this species in smaller streams such as the Clinch River and Paint Rock River may result from sub-optimal habitat for this otherwise large river species (USFWS, 1985).

Known threats include modification of habitat (e.g., dams and dredging), degradation of water quality, and over harvest by commercial mussel industry. Also, siltation, pollution, and channelization in Ohio. Continued threats to the survival of this species include alteration or destruction of stream habitat due to impoundment for flood control, navigation, hydroelectric power, and recreation; siltation due to strip mining, coal washing, dredging, farming, logging, and road construction; and pollution from municipal, industrial, and agricultural waste discharges (USFWS, 1985).

E.13 Scaleshell

This species was listed as federally endangered in the U.S. in 2001 and a recovery plan has been drafted (USFWS, 2004).This species has experienced a severe reduction in extant occurrences (approximately 75% reduction in number of streams) that has reduced this species from a fairly widespread species to a "regional endemic" in the Interior Highlands region. Subnational extirpations have occurred in Alabama, Iowa, Illinois, Indiana, Kentucky, Minnesota, Ohio, Tennessee, and Wisconsin. While it exists in 14 streams, only three or four populations are thought to be stable and most occurrences are widely disjunct (NatureServe. 2014).

This species is severely impacted by alteration and inundation of channels, siltation from agriculture and clear-cutting, chemical and organic pollution. The decline of scaleshell is primarily due to threats that cause habitat loss and degradation from construction activities and intensive land use (USFWS, 2004).

Szymanski (1998) lists the following threats:

(1) destruction, modification, or curtailment of habitat or range: This species has suffered one of the greatest range restrictions in North America. Degradation continues to threaten populations. Major causes are channelization, damming and impoundment, sedimentation, and nonpoint and point source pollution.
(2) overutilization for scientific or commercial purposes: This is unlikely due to the small size of this species. Extirpated populations may have been subjected to overharvesting and today incidental collecting may be a problem.
(3) disease and predation: Small mammal predation could potentially pose a problem for populations especially for small populations in Arkansas and Oklahoma.
(4) inadequacy of existing regulatory mechanisms: The species is not afforded state protection in Arkansas but Missouri and Oklahoma afford state protective status.

The scaleshell has been found completely buried in the substrate down to depths of 15 cm (Oesch, 1984; 1995). It occurs in medium to large rivers with low to moderate gradients in a variety of stream habitats including gravel, cobble, boulders, and occasionally mud or sand substrates (Buchanan, 1980; 1994; Oesch, 1995). Although always somewhat rare, this species historically was not habitat limited and once occupied a wide variety of habitats including riffle areas with assemblages of gravel, cobble, boulder, and occasionally mud or sand; as well as big rivers with muddy bottoms (Szymanski, 1998). Currently it is more restricted to rivers with relatively good water quality (Oesch, 1995) in stretches with stable channels (Buchanan, 1980).

E.14 Ring pink

This species was listed as federally endangered in the U.S. on September 29, 1989 and a recovery plan created (USFWS, 1991). This species is extirpated from nearly all of its formerly wide range through loss of habitat and is reduced to five populations, most of which are represented by few collected specimens and are not viable.

Ring pink is known from five relic populations (USFWS, 1991), but only two, or possibly three are likely viable. In September 1997 one live specimen was found for the first time since the 1960's in the Green River upstream of Mammoth Cave National Park, approx. 13 river miles from the Munfordville population in Kentucky (Butler et al., 1997).

Dennis (1984) characterized preferred habitat as large rivers, but it has been reported from the Duck River indicating it can tolerate medium rivers (Mirarchi et al., 2004). Gravel and sand bars are preferred (Neel and Allen, 1964; Hickman, 1937). Because of reservoir construction on these large rivers, most historic occurrences have been inundated (Bogan and Parmalee, 1983).

Loss of habitat due to impoundments (which similarly affected fish hosts) is probably the primary cause for decline. Other threats include gravel dredging, channel maintenance, and incidental take from commercial mussel harvesting. The Green River population is threatened by diminished water quality due to oil and gas production. The Kanawha River population may be threatened by a barge terminal. Individuals still surviving in the Tennessee and Cumberland Rivers are potentially threatened by gravel dredging, channel maintenance, and commercial mussel fishing (mostly historically) through incidental take (USFWS, 1991; 2006).

E.15 Littlewing pearlymussel

This species was listed as federally endangered in the U.S. on November 14, 1988 (USFWS, 1988) and a recovery plan created (USFWS, 1989). Littlewing pearlymussel is a declining regional endemic species formerly known from 27 river systems with only very few widely disjunct populations remaining at fewer than a dozen sites. Habitat loss continues to threaten the species and some populations are no longer viable.

Surveys in 1986 found this species in six short stream reaches of the Tennessee and Cumberland River basins. Over 55 potential or historic habitat areas were searched. It is now believed to exist in only three sites in southeastern Kentucky in the Cumberland River drainage below Cumberland Falls (Cicerello and Schuster, 2003), two sites in southeastern Virginia, and one site in central Tennessee (upper Caney Fork River drainage) (USFWS, 1989; Parmalee and Bogan, 1998).

Only 17 live mussels were found during extensive surveys in 1986. It is likely that each of the remaining half dozen or so populations, with the exception of Horse Lick Creek and Big South Fork Cumberland River, contain less than 500 individuals (USFWS, 1989).

This species is most common at the head of riffles, but also found in and below riffles on sand and gravel substrates with scattered cobbles. It also inhabits sand pockets between rocks, cobbles and boulders, and underneath large rocks (Gordon and Layzer, 1989). It is restricted to small, cool streams. It is usually found lying on top or partially buried in sand and fine gravel between cobble in only 6 to 10 inches of water. It is usually found at the head of riffles (Bogan and Parmalee, 1983; Stansbery, 1976).

Deterioration of water quality, especially from acid mine drainage is the primary threat to the species. Development of coal, oil, and/or natural gas reserves in the watersheds of the Horse Lick Creek, Big South Fork Cumberland River, Little South Fork Cumberland River, Clinch River, and Cane Creek are potential threats. All populations could potentially be impacted by road construction, stream channel modifications, logging activities, agricultural activities, impoundments, land use changes, and pesticide use. Because all populations inhabit only short stream reaches within 1 to 5 miles of bridges and fords, they are also vulnerable to toxic spills (USFWS, 1989). It is also effected by domestic pollution and impoundments (Bogan and Parmalee, 1983). Historically, many of the isolated populations have been extirpated from acid mine drainage, domestic pollution, and impoundment of rivers which it inhabited (Parmalee and Bogan, 1998).

E.16 White wartyback

This species was listed as federally endangered, nonessential experimental population in the U.S. on June 14, 1976 and a recovery plan created (USFWS, 1984). Long-term viability of this mussel (if in fact it still exists) is doubtful. No known living populations have been found in numerous surveys of the Tennessee River since the 1960s although fresh dead specimens were found in 1979 and 1982. The only known extant population might occur in tailwaters of Wilson Dam on Tennessee River where it is rare; otherwise all occurrences throughout its entire historic range appear to be extirpated.

Historically, this species was widely distributed in the Ohio, Cumberland, and Tennessee drainages including the Wabash, Ohio, Kanawha, Cumberland, Holston, and Tennessee Rivers (USFWS, 1984). No live specimens have been found in the Wabash, Ohio, Kanawha, Cumberland, or Holston rivers since around the turn of the century. It possibly still exists in a very short reach of the Tennessee River mainstem below Pickwick Dam near Savannah, Tennessee, near river mile 207 because all of the most recent historical records were from the original Tennessee River channel (USFWS, 1984; Parmalee and Bogan, 1998). The only other potential extant population is in the tailwaters of Wilson Dam on the Tennessee River where it is rare (Mirarchi et al., 2004). It historically occurred in the Wabash mainstem in Indiana (Fisher, 2006).

The only recent record was the collection of fresh dead shells from a commercial shell pile in 1979 and 1982 below Pickwick Dam near Savannah, Tennessee (USFWS, 1984). Both collections were older specimens. Currently the only known extant population might occur in the tailwaters of Wilson Dam on the Tennessee River in northwest Alabama where it is rare (Mirarchi et al., 2004). No live specimens have been collected in over 30 years and no estimates of population size or abundance have been made but what few live specimens have been found have been single old individuals.

This species is restricted to riffles in large rivers; most of which are now impounded. Smith (1971) ranked the causes of extirpation or declines in fish species as follows: siltation, drainage of bottomland lakes, swamps, and prairie marshes, desiccation during drought, species introductions, pollution, impoundments, and increased water temperatures. All of these factors render habitats unsuitable, cause extirpations, and lead to the isolation of populations. USFWS (1984) lists the following reasons for decline: impoundment (for flood control, navigation, hydroelectric power production, and recreation) causing altered temperature regime, extreme water level fluctuations, reduced turbidity, seasonal oxygen deficits, and high concentrations of heavy metals; siltation (from strip mining, coal washing, dredging, farming, logging, and road construction) causing increased silt transport, increased turbidity, erosion of bank habitat, elimination of host fish; pollution (municipal, agricultural, and industrial waste discharges). If any populations still remain, they are isolated and extremely small with poor viability in the Tennessee River with poor dispersal capability. No live specimens have been found in the Holston River, Cumberland River, Ohio River, Wabash River, and Konawha River since before the turn of the 20th Century. It is extirpated from Kentucky but formerly occurred in the Ohio and lower Cumberland Rivers (Cicerello and Schuster, 2003). It is extirpated from the McAlpine dam pool in the Ohio River at Louisville, Kentucky (and Indiana) (Watters and Flaute, 2010).

E.17 Orangefoot pimpleback

On June 14, 1976, the orangefoot pimpleback (pearlymussel) was designated as endangered and a recovery plan addressing this species was approved September 30, 1984 (USFWS, 1984). This species is found in medium to large rivers in sand, gravel, and cobble substrates in riffles and shoals in deep water and steady currents as well as some shallower shoals and riffles (Gordon and Layzer, 1989; Bogan and Parmalee, 1983; Cummings and Mayer, 1992; USFWS, 1984).

The range of this species has been reduced to over 70% with even greater declines (likely > 80%) in occupied habitat. Long-term viability is doubtful as this species exists in small numbers in widely disjunct, localized beds. Continued human modification of the large rivers of the eastern United States and the impacts caused by zebra mussels will likely eliminate this species. Presently, this species is restricted to the Tennessee, Cumberland, and lower Ohio rivers where it is rare. Parmalee et al. (1980) reported finding live individuals near Bartlett's Bar on the Cumberland River in 1979 and represent the only live records in the river since Neel and Allen (1964). In Kentucky, it is sporadic in the Ohio River and rare in the Tennessee River (Cicerello and Schuster, 2003).

Pollution through point (industrial and residential discharge) and non-point (siltation, herbicide and fertilizer run-off) sources is perhaps the greatest on-going threat to this species and most freshwater mussels. Lowered dissolved oxygen content and elevated ammonia levels (frequently associated with agricultural runoff and sewage discharge) have been shown to be lethal to some species of freshwater naiads (Horne and McIntosh, 1979). Residential, mineral and industrial development also pose a significant threat. Rotenone, a toxin used to kill fish in bodies of water for increased sport fishery quality, has been shown to be lethal to mussels as well (Heard, 1970). Destruction of habitat through stream channelization and maintenance and the construction of dams is still a threat in some areas. Impoundments reduce currents that are necessary for basic physiological activities such as feeding, waste removal and reproduction. In addition, reduced water flow typically results in a reduction in water oxygen levels and a settling out of suspended solids (silt, etc.), both of which are detrimental. Dredging of streams has an immediate effect on existing populations by physically removing and destroying individuals. Dredging also affects the long-term recolonization abilities by destroying much of the potential habitat, making the substrates and flow rates uniform throughout the system.

The federal recovery plan (USFWS, 1984) lists the following threats: impoundment (for flood control, navigation, hydroelectric power, and recreation), siltation (due to strip mining, coal washing, dredging, farming, logging, and road construction), and pollution (municipal, agricultural, and industrial waste discharges).

E.18 Sheepnose

This species was listed as a U.S. Federal endangered species on March 13, 2012. The sheepnose has been extirpated throughout much of its former range or reduced to several dozen isolated populations. This species has been eliminated from two-thirds of the total number of streams from which it was historically known although it still has a very wide distribution with dozens of occurrences in the Mississippi and Ohio basins (over two dozen streams in 14 states). The majority of the remaining populations are small and geographically isolated (NatureServe 2014).

Smith (1971) ranked the causes of extirpation or declines in mussel species as follows: siltation, drainage of bottomland lakes, swamps, and prairie marshes, desiccation during drought, species introductions, pollution, impoundments, and increased water temperatures. All of these factors render habitats unsuitable, cause extirpations, and lead to the isolation of populations.

Pollution through point (industrial and residential discharge) and non-point (siltation, herbicide and fertilizer run-off) sources is perhaps the greatest on-going threat to this species and most freshwater mussels. Lowered dissolved oxygen content and elevated ammonia levels (frequently associated with agricultural runoff and sewage discharge) have been shown to be lethal to some species of freshwater naiads (Horne and McIntosh, 1979). Residential, mineral and industrial development also pose a significant threat. Rotenone, a toxin used to kill fish in bodies of water for increased sport fishery quality, has been shown to be lethal to mussels as well (Heard, 1970). Destruction of habitat through stream channelization and maintenance and the construction of dams is still a threat in some areas.

Impoundments reduce currents that are necessary for basic physiological activities such as feeding, waste removal and reproduction. In addition, reduced water flow typically results in a reduction in water oxygen levels and a settling out of suspended solids (silt, etc.), both of which are detrimental. Dredging of streams has an immediate effect on existing populations by physically removing and destroying individuals. Dredging also affects the long-term recolonization abilities by destroying much of the potential habitat, making the substrates and flow rates uniform throughout the system.

Channelization impacts a stream's physical characteristics (e.g., accelerated erosion, reduced depth, decreased habitat diversity, geomorphic instability, riparian canopy loss) and biological composition (e.g., decreased fish and mussel diversity, changed species composition and abundance, decreased biomass, and reduced growth rates) (Hartfield, 1993; Hubbard et al., 1993).

Heavy metal-rich drainage from coal mining and associated sedimentation have adversely impacted portions of the upper Tennessee River system in Virginia. Sedimentation is a pervasive problem in streams and has been implicated in the decline of stream mussel populations (Ellis, 1936; Marking and Bills, 1979; Vannote and Minshall, 1982; Dennis, 1984; Brim Box, 1999; Fraley and Ahlstedt, 2000).

No specific studies have considered this species. Densities have been determined in a few surveys (e.g., Jenkinson and Ahlstedt, 1988; Layzer and Gordon, 1990).

E.19 Clubshell

This subspecies was listed as federally endangered, nonessential experimental population on January 22, 1992 in the U.S. and a recovery plan created (USFWS, 1994). This species has been extirpated from most of its range in this century (probably less than 20% of historical range remains). Continued loss of habitat and water quality deterioration threaten remaining populations.

It has been found in short reaches of 12 streams (USFWS, 1993; 1994). Small numbers were found in Kentucky although it is rare in the upper Green River (Cicerello and Schuster, 2003).

E.20 Rough pigtoe

This species was listed as federally endangered, nonessential experimental population on April 7, 1987 and a recovery plan was created (USFWS, 1984). This species is found in medium to large rivers (20 m wide or greater) in sand, gravel, and cobble substrates and in shoals. It is occasionally found on flats and muddy sand (Gordon and Layzer, 1989; USFWS, 1984). Distribution is greatly fragmented and the remaining occurrences are few and highly disjunct. Long-term viability of most populations is questionable and questionable taxonomic status and problems in identification complicate the problem.

Although reported by Parmalee et al. (1980) from the middle Cumberland River between 1977 and 1979, it was not found in recent surveys by Tennessee Valley Authority (1976) or Sickel and Chandler (1996). It is present in the Green River, Kentucky between locks 4 and 5 and in the Barren River (Green River tributary in Kentucky) below Lock and Dam 1 (USFWS, 1984). Clarke (1983) found a single living specimen in the Green River near Glenmore, Kentucky.

In the 1980s, this species was confined to under 20 sites in the Tennessee, Clinch, Cumberland, Barren and Green rivers (USFWS, 1984); fewer than half are still likely extant in the Green River below Lock and Dam No. 5 near Glenmore in Warren Co. to Lock 4 near Woodbury, Kentucky; Barren River below Lock and Dam No. 1 near Bowling Green, Kentucky to the mouth of the river (USFWS., 1984). Clarke (1983) reported live specimens from the Green River and Barren Rivers, Kentucky (live specimens only in Green River near Glenmore). In Kentucky, it is sporadic in the upper Green River where it is considered rare (Cicerello and Schuster, 2003). It has been collected in Kentucky in the Middle Green and Barren Rivers (Cochran and Layzer, 1993).

Smith (1971) ranked the causes of extirpation or declines in mussel species as follows: siltation, drainage of bottomland lakes, swamps, and prairie marshes, desiccation during drought, species introductions, pollution, impoundments, and increased water temperatures. All of these factors render habitats unsuitable, cause extirpations, and lead to the isolation of populations.

Pollution through point (industrial and residential discharge) and non-point (siltation, herbicide and fertilizer run-off) sources is perhaps the greatest on-going threat to this species and most freshwater mussels. Lowered dissolved oxygen content and elevated ammonia levels (frequently associated with agricultural runoff and sewage discharge) have been shown to be lethal to some species of freshwater naiads (Horne and McIntosh, 1979). Residential, mineral and industrial development also pose a significant threat. Rotenone, a toxin used to kill fish in bodies of water for increased sport fishery quality, has been shown to be lethal to mussels as well (Heard, 1970). Destruction of habitat through stream channelization and maintenance and the construction of dams is still a threat in some areas. Impoundments reduce currents that are necessary for basic physiological activities such as feeding, waste removal and reproduction. In addition, reduced water flow typically results in a reduction in water oxygen levels and a settling out of suspended solids (silt, etc.), both of which are detrimental. Dredging of streams has an immediate effect on existing populations by physically removing and destroying individuals. Dredging also affects the long-term recolonization abilities by destroying much of the potential habitat, making the substrates and flow rates uniform throughout the system.

The federal recovery plan (USFWS, 1984) lists the following threats: impoundment (for flood control, navigation, hydroelectric power, and recreation), siltation (due to strip mining, coal washing, dredging, farming, logging, and road construction), pollution (from municipal, agricultural, and industrial discharges). Invasion by zebra mussels is a recent threat to this species' survival.

E.21 Slabside pearlymussel

The Slabside pearlymussel was listed as endangered on September 26, 2013. The slabside pearlymussel is primarily a large creek to moderately-sized river species, inhabiting sand, fine gravel, and cobble substrates in relatively shallow riffles and shoals with moderate current (Parmalee and Bogan, 1998). It requires flowing, well-oxygenated waters to thrive.

This species has been eliminated from at least three-fifths of the total number of streams where it was historically recorded. It is experiencing recent and continuing sharp declines in occurrences;

with the majority of surviving individuals apparently restricted to two to three populations. Continuing long-term viability at all extant occurrences is questionable.

The species is restricted to the Cumberland (in Kentucky and Tennessee) and Tennessee (in Alabama, Tennessee, and Virginia) River systems. Historically, this species occurred in the lower Cumberland River main stem from about Caney Fork downstream to the vicinity of the Kentucky State line, and in the Tennessee River main stem from eastern Tennessee to western Tennessee. It generally has been considered a Tennessee River endemic (Simpson, 1914; Bogan and Parmalee, 1983). Recent finds of relict specimens (e.g., Parmalee et al., 1980; Schuster, 1988) confirm it as a historical component of the Cumberland River fauna (Starnes and Bogan, 1988; Gordon and Layzer, 1989) however, it is apparently extirpated from the entire Cumberland River system.

The decline of the slabside pearlymussel in the Cumberlandian Region and other mussel species in the eastern United States is primarily the result of habitat loss and degradation. Chief among the causes of decline are impoundments, stream channel alterations, water pollution, and sedimentation. The majority of the Tennessee and Cumberland River main stems and many of their largest tributaries are now impounded. The species is further impacted by channel alterations, inundation by reservoirs, siltation by agriculture and clear-cutting, chemical and organic pollution, and commercial clamming. Gravel mining activities are a threat in the Powell and Elk Rivers as well as coal mining activities in the upper Tennessee River system (USFWS, 2003). A quantitative study by Ahlstedt and Tuberville (1997) found long-term decline in mussel composition in the Powell River was attributed to general stream degradation due to coal mining activities. Population losses due to impoundments have probably contributed more to the decline of the slabside pearlymussel and other Cumberlandian Region mussels than any other single factor (USFWS 2010) (NatureServe. 2014).

E.22 Fat pocketbook

This species was listed as federally endangered in the U.S. on June 14, 1976 and a recovery plan (USFWS, 1989) created. This species is found in sand, mud, and fine gravel substrates and flowing water and is also found in large rivers in slow-flowing water (often near the bank) in mud or sand (Cummings et al., 1990). Recently, it has been found to be tolerant of depositional areas that are usually unfavorable to other mussel species and is in fact, not a lotic species as indicated in the Recovery Plan (USFWS, 1989) that is negatively affected by high sedimentation rates. In fact, man-made ditches and existing bayous, sloughs, and streams in the St. Francis watershed provide suitable habitat (Miller and Payne, 2005).

Based largely on museum records, this species was formerly present in the upper Mississippi River (above St. Louis, Missouri); the Wabash River, Indiana; and the St. Francis River, Arkansas (Harris et al., 1997), including: Minnesota, Wisconsin, Iowa, Illinois, Indiana, Missouri, Kentucky, and Arkansas (USFWS, 1989). The St. Francis River is the center of historical distribution and maintains the best habitat and healthiest populations today. Since 1970, the species has been found extant in portions of the St. Francis River (Jenkinson and Ahlstedt, 1995), with scattered records from the Wabash and Ohio Rivers in Indiana and Kentucky (Sickel, 1987; Cummings et al. 1990; Cummings and Mayer, 1993).

The fat pocketbook is presently thought to be restricted to about 20 sites in the lower Wabash and Ohio rivers, the St. Francis River system of Arkansas, and the boot heel of Missouri (Ahlstedt and Jenkinson, 1991; Jenkinson and Ahlstedt, 1995; Sickel, 1987; Cummings and Mayer, 1993; 1997; Harris and Gordon, 1987). Sites include the lower Wabash River, Indiana; White River, Indiana; lower Cumberland River, Kentucky; and a few dead young shells from the upper Mississippi River in Pike Co., Missouri (also a reintroduction site) (USFWS, 1989).

Dredging and impoundments are the primary cause for decline. Mussels are particularly susceptible to dredging and must be relocated in order to survive. The Upper Mississippi River has been impounded for navigation and is dredged routinely and this species, once widespread in the river, has disappeared in recent years. The largest population occurs in the St. Francis Floodway. This watershed has been substantially altered by local interests and the U.S. Army Corp to subsidize agricultural interests. Most of the stream channels have been dredged or straightened under the guise of flood control. Much of the substrate of the White River, Arkansas, consists of shifting sandbars with stable substrate only along the bank where some non-dredged mud ledges remain (USFWS, 1989). Siltation has also been associated with reduction in populations of this species. Pollution may also affect this species but the effects have not been well studied (USFWS, 1989).

E.23 Fluted kidneyshell

The Fluted kidneyshell was listed as endangered on September 26, 2013 (also designated critical habitat). The fluted kidneyshell is restricted to the Cumberland River in Kentucky. Currently it is limited to nine streams in the Cumberland River system (six isolated populations) and seven streams (four isolated populations) in the Tennessee River system. Cumberland River system tributaries with extant populations include the Middle Fork Rockcastle River, Horse Lick Creek, Buck Creek, Rock Creek, Kennedy Creek, Little South Fork, Big South Fork, Wolf River and West Fork Obey River. The decline of the fluted kidneyshell in the Cumberlandian Region is primarily the result of habitat loss and degradation (NatureServe. 2014).

The decline of the fluted kidneyshell in the Cumberlandian Region and other mussel species in the eastern United States is primarily the result of habitat loss and degradation. These losses have been well documented for over 130 years. Chief among the causes of decline are impoundments, stream channel alterations, water pollution, and sedimentation. Instream gravel mining has also been implicated in the destruction of mussel populations. Heavy-metal rich drainage from coal mining and associated sedimentation have adversely impacted upper Cumberland River system streams with diverse historical mussel faunas. Sediment from the upper Clinch River, where the largest population of the fluted kidneyshell remains, was found to be toxic to juvenile mussels (USFWS 2001)..

Other threats include: overutilization for commercial, recreational, scientific, or educational purposes (minimal threat: not a commercially valuable species, but may be increasingly sought by collectors with its increasing rarity); disease or predation (disease largely unknown; predation is a localized threat); inadequacy of existing regulatory mechanisms (Alabama, Kentucky, Tennessee, and Virginia prohibit the taking of mussels for scientific purposes without a State collecting permit, however, enforcement of this permit requirement is difficult) (USFWS, 2001).

E.24 Rabbitsfoot

The Rabbitsfoot was listed as threatened on September 17, 2013. Rabbitsfoot populations are considered to be extant in 46 streams in 13 states and 5 USFWS regions including the Cumberland River System in Kentucky. Extant rabbitsfoot populations occur in Kentucky's Ohio River, South Fork Kentucky River, Green River, Barren River, Rough River, Red River and Tennessee River (NatureServe 2014).

The greatest threat to this species in the Cumberlandian region is habitat alteration. The chief causes of the decline of the Rabbitsfoot are impoundments, channelization, chemical contaminants, mining, and sedimentation (Neves, 1991, 1993; Williams et al., 1993; Neves et al., 1997; Watters, 2000). The decline, extirpation, and extinction of mussel species is overwhelmingly attributed to habitat alteration and destruction (Neves, 1993), primarily manifest through impounding riverine systems. Historical population losses due to impoundments have probably contributed more to the decline and imperilment of the rabbitsfoot than any other single factor. Dams interrupt most of a river's ecological processes by modifying flood pulses; controlling impounded water elevations; altering water flow, sediments, nutrients, and energy inputs and outputs; increasing depth; decreasing habitat heterogeneity; decreasing stability due to subsequent sedimentation; blocking host fish passage; and isolating mussel populations from fish hosts. Impoundments also dramatically modify riffle and shoal habitats and result in the loss of mussel resources, especially in highly diverse larger rivers. The reproductive process of riverine mussels is generally disrupted by impoundments. The majority of the main stems of the Ohio, Cumberland, Tennessee River, and White Rivers and many of their largest tributaries, including reaches that were once strongholds for the rabbitsfoot, are now impounded and in many cases impacted by tailwater conditions unsuitable for this species. Dams on many streams in the Cumberlandian region have directly destroyed rabbitsfoot habitat. These include nine on the main stem Tennessee River, and others on the Holston, Little Tennessee, Clinch, Elk, and Duck Rivers, and Bear Creek.

Negative impacts associated with gravel mining include stream channel modifications (e.g., altered habitat, disrupted flow patterns, sediment transport), water quality modifications (e.g., increased turbidity, reduced light penetration, increased temperature), macroinvertebrate population changes (e.g., elimination, habitat disruption, increased sedimentation), and changes in fish populations (e.g., impacts to spawning and nursery habitat, food web disruptions). Sedimentation, including siltation, has been implicated in the decline of stream mussel populations. Many rabbitsfoot streams in the Midwest and Southeast have increased turbidity levels due to siltation. Agricultural activities produce the most significant amount of sediment that enters streams. Developmental activities may impact streams where adequate streamside buffers are not maintained and erosion of impacted land is allowed to freely enter streams. These may include highway construction, building construction, general infrastructure (e.g., utilities, sewer systems), and recreation facilities (e.g., golf courses) (NatureServe 2014).

E.25 Winged mapleleaf

This species was designated as U.S. federally endangered, nonessential experimental population on June 20, 1991, a recovery plan (USFWS, 1997) was drafted and reintroduction efforts are underway (Hove et al., 2002; 2003). The excessive loss of occurrences due to habitat alteration threatens this species with extinction. Due to the mistaken synonymy of it under *Quadrula quadrula* by Neel (1941) and its relative rarity compared to the latter species, the declines in its populations were not recognized until recently. It apparently persists in a short section of the lower St. Croix River along the Minnesota/Wisconsin border and the Kiamichi River in Oklahoma. Extant occurrences have declined to a critical level. The species is so rare that it had not been generally recognized as a valid species for approximately 50 years.

Chemical and organic pollution, alteration and inundation of river channels and siltation continue to have, a severe negative impact on this species. Commercial harvest of shells may also be a threat. A single catastrophic event could possibly cause the extinction of this species. The availability of suitable habitat is a major concern for the continued existence of this species. The species is vulnerable to stochastic events and, as a result of its small, fragmented distribution, has difficulty with recruitment (USFWS, 1997).

This species is nearly extirpated from its entire historic range (including Alabama, Iowa, Illinois, Indiana, likely Kentucky, Nebraska, Ohio, and Tennessee) except for a few remnant populations (USFWS, 1997). Total historic distribution (most extirpated) includes much of the Mississippi River from Missouri to Wisconsin; the Red, Kiamichi, Boggy, and Little Rivers in Oklahoma; the Whitewater, Verdigris, fall, and Neosho Rivers in Kansas, the Ohio River in Ohio and Indiana; the Licking River in Kentucky; the Tennessee, Duck, Cumberland, and Harpeth Rivers in Tennessee; the Wabash and White Rivers in Indiana; the Scioto River at Columbus and Cincinnati and Raccoon Creek in Ohio (Watters et al., 2009), the Kaskaskia, Illinois, Spoon, and Sangamon Rivers in Illinois, Soldier Creek in Kansas and the Blue River and Bow Creek in Nebraska; the Des Moines, Raccoon, Iowa, and Cedar Rivers in Iowa; and the Wisconsin, Baraboo, and St. Croix Rivers in Wisconsin (USFWS, 1997).

E26 Cumberland bean

This species was listed as federally endangered, nonessential experimental population in the U.S. on June 14, 1976 and a recovery plan created (USFWS, 1984). This species is limited to clean, fast flowing rivers in riffle areas only on gravel and sand substrates. Ideal habitat conditions are hard to find as much of the historical habitat has been degraded and may be incapable of harboring the species (USFWS, 2010). Once found throughout the Cumberlandian region, it is now restricted to four rivers and has become extirpated from a significant portion of its range to where only a few disjunct occurrences remain, some with questionable viability.

The range of the species is restricted to the lower and upper tributary streams of the Tennessee River and the upper tributary streams of the Cumberland River. In the upper Cumberland River drainage it is known from the Cumberland River from Pulaski County to Cumberland Falls, Whitley County, Kentucky (Cicerello and Schuster, 2003). It is known from Rockcastle River and its tributary Laurel Fork, Jackson, Rockcastle, and Laurel Counties, Kentucky; also Little South Fork of the Cumberland River, Wayne County, Kentucky and the lower Obey River, Clay County, Tennessee (Bogan and Parmalee, 1983; USFWS, 1984). Its current range includes the Hiwasee River, Polk County, Tennessee and North Carolina; the lower Obey River, Clay County, Tennessee; Rockcastle River and its tributary Laurel Fork in Jackson, Rockcastle, and

Laurel Counties and the Little South Fork of the Cumberland River, Wayne County, all in Kentucky (Bogan and Parmalee, 1983). It has been extirpated from Virginia, Alabama, and the mainstem of the Cumberland River in Kentucky (Mirarchi et al., 2004).

Less than ten occurrences exist in Kentucky including Little South Fork Cumberland River (USFWS, 1984) (although this population may be extirpated due to coal-related spills and water quality changes in the 1980s (USFWS, 2010). It was recently reported by Johnson et al. (2005) from the Hiwassee River inside and adjacent to Cherokee National Forest, Polk Co., Tennessee. Clarke (1983) listed occurrences in the Cumberland River just below Cumberland Falls, Buck Creek, Rockcastle River, and Little South Fork Cumberland River in Kentucky. A total of 49 live individuals were reported from 7 sites in the Big South Fork Cumberland River system in Kentucky and Tennessee (USFWS, 2010). The species is most viable in the Cumberland System (USFWS, 1984) with Sinking Creek (Rockcastle River tributary), Kentucky, having the best population (USFWS, 2010).

Reasons for decline include impoundment (for flood control, navigation, hydroelectric power production, and recreation), siltation (due to strip mining, coal washing, dredging, farming, logging, and road construction), and pollution (municipal, agricultural, and industrial waste discharges; such as coal mine acids, gravel dredging, fertilizers, pesticides, industrial spills) (USFWS, 1984).

Acid mine wastes and resulting impacts to water quality are either known and/or suspected causes in streams like the Little South Fork, Big South Fork, and Rockcastle River drainages. Threats from transportation corridors, coal mines, and oil and gas wells were still considered dominant threats to Big South Fork populations as recently as 2005. In-stream gravel mining and nonpoint source pollution to water quality and habitat are considered impacts in Buck Creek. Natural droughts, as well as water withdrawals for human use, can impact water levels. Changes in land use in the recharge area can accelerate pollutants delivery. Other potential threats include contaminant spills, mining (e.g. coal, oil, gas, and gravel), siltation from land use practices, and stream impoundments (USFWS, 2010).

X. Analysis of the Potential of Selenium to Affect Endangered and Threatened Species

A. Bats

Corynorhinus (=plecotus) townsendii virginianus, Virginia big-eared bat
Myotis grisescens, Gray bat
Myotis septentrionalis, Northern long-eared bat
Myotis sodalis, Indiana bat

A.1 General analysis

Four bat species are considered in this evaluation. Major risks to these species include disease, spelunking or cave recreation that disturbs sensitive taxa, and terrestrial habitat impacts—including loss of habitat and roost sites due to impoundment, stream channelization, housing development, and clear-cutting or other forest management practices (Adam et al. 1994;

NatureServe 2014a,b). Bats are not aquatic organisms; however, the four taxa under consideration for this evaluation do depend on aquatic systems for drinking water, foraging habitat, and prey (which include aquatic insects).

A decline in water quality would affect bats through direct consumption, since they can rely on surface water for drinking (USFWS 2006). This view is supported by habitat data that indicate the taxa focus on waters with fair-to-good water quality, which may reflect diet preference but may also be related to water consumption (Clare et al. 2011).

Many of the taxa have small foraging ranges located close to their roosts, to which they retain a strong fidelity (Adam et al. 1994; Johnson et al. 2014; Silvis et al. 2014). Reduction in the foraging habitat or its prey production would impact their survival since taxa (e.g., *Myotis sodalis*) may eat up to half their body weight in insects (USFWS 2006, 2007a; NatureServe 2014b). Foraging habitat for some of the bats is often associated with hydric areas like bottomland, riparian, and wetland habitat adjacent to water (Carter 2006).

Bat diets include a large variety of insects (Tuttle et al. 2006), some of which include representative aquatic taxa (e.g., Ephemeroptera, Trichoptera, Diptera), but which are mostly dominated by species with primarily terrestrial representatives (e.g., Hemiptera, Hymenoptera, Lepidoptera, Neuroptera, Coleoptera) (Best et al. 1997; Lee and McCracken 2004; NatureServe 2014a, 2014b; Ober and Hayes 2008). Prey influence toxicity as well as energetics, since contaminants can accumulate in prey.

Bats are being negatively affected by disturbance or loss of summer habitat. Loss and degradation of summer habitat and roost sites due to impoundment, stream channelization, housing development, clear cutting for agricultural use (Herkert 1992), or incompatible forest management practices that result in a shortage of the microhabitats used for maternity roosts may be the primary factors in recent population declines (Sparks et al. 2005).

A.2 Selenium Analysis:

Mammals are not as sensitive to Se as fish and birds (Ohlendorf 1989; Janz *et al*. 2010). In studies conducted between 1984 and 1986 at Kesterson National Wildlife Refuge in central California, concentrations of Se were measured in various tissues (blood, liver, hair) and feces of 10 species of small mammals (Ohlendorf 1989). Results demonstrated a strong relationship to environmental Se concentrations, with the highest tissue Se concentrations associated with the most contaminated sites (Ohlendorf 1989). In spite of higher Se bioaccumulation in the exposed mammals, there were no apparent changes in the health of the organisms between exposed and reference areas. The exception was that no pregnant voles or mice were found in Kesterson, whereas pregnant individuals were found in the reference area. Although this finding might suggest reproductive failure, Se could not be definitively linked to the observation (Ohlendorf 1989). In comparison, at the same locations there were overt and often severe signs of acute and chronic Se toxicity observed in both fish and birds (Ohlendorf 1989).

A.3 Specific Taxa Literature Evidence Relevant To Analysis

Corynorhinus (=plecotus) townsendii virginianus, Virginia big-eared bat

The Virginia big-eared bat is reported to consume lepidopteran (moths and butterflies), coleopteran (beetle), dipteran (true flies), and hymenopteran (sawflies, wasps, bees, and ants) prey (Burford and Lacki 1998; NatureServe 2014a).

Myotis grisescens, Gray bat

Gray bats are reported to consume lepidopteran, coleopteran, dipteran, and ephemeropteran (mayfly) prey (Best et al. 1997; Brack and Laval 2006; NatureServe 2014b).

Myotis septentrionalis, Northern long-eared bat

Northern long-eared bats are reported to consume lepidopteran, coleopteran, dipteran, ephemeropteran, neuropteran (lacewings), hymenopteran, hemipteran (true bugs), trichopteran (caddisfly), and arachnid (spider) prey (Carter et al. 2003; Dodd et al. 2012; Feldhammer et al. 2009; Lacki et al. 2009; Lee and McCracken 2004; NatureServe 2014c).

Myotis sodalis, Indiana bat

Indiana bats are reported to consume nine orders and 26 families (Tuttle et al. 2006), including lepidopteran, coleopteran, dipteran, and trichopteran prey (Kurta and Whitaker Jr. 1998; Ober and Hayes 2008).

B. Birds

Calidris canutus rufa, Red knot (migrant only)
Charadrius melodus, Piping plover (migrant only)
Grus Americana, Whooping crane (migrant only)
Sterna antillarum athalassos, Interior least tern

B.1 General analysis

There are four bird species considered in this evaluation. Red knots and piping plovers occur in Kentucky only during the spring and fall migration periods, while the interior least tern is a year-round resident of the lower Ohio and Mississippi Rivers in Kentucky (NatureServe 2014d, 2014e). Whooping cranes have been designated as a nonessential population in Kentucky. Piping plovers may migrate through Kentucky to feed in the area of the Kentucky Lake but they are labeled “conservation status not applicable” and may possibly be extirpated in Kentucky (NatureServe 2014d; USFWS 2014a). Primary threats to all four species are destruction and degradation of summer and winter habitat, shoreline erosion, human disturbance of nesting and foraging birds, and predation (Burger 1993).

Red knots, piping plovers, and whooping cranes are susceptible to habitat change and loss (e.g., human disturbance of nesting and foraging habitats), toxins, red tides, predation, disease, collisions with wind turbines, storms, and hunting (NatureServe 2014d, 2014e; USFWS 2013a). For the interior least terns, one major reason for the decline in populations was extensive plume hunting. Nesting populations have declined due to human activities such as modification of river flow (e.g., damming), channelization, bank stabilization, desalination projects, irrigation, water pollution from pesticides, and grazing cattle trampling on eggs (NatureServe 2014f; TXPWS n.d.). Increased river flows can result in reduced availability of sand bars and bare islands that the interior least terns use for nesting, and changes in the river flow can result in loss of aquatic habitat diversity leading to a decrease in the abundance and composition of fish prey. Other factors in population decline include birds and mammals that prey on eggs and young, severe weather affecting nesting habits, chemical spills and pesticides, and heavy metal pollution (NatureServe 2014f; TXPWS n.d.).

The diet of the red knot, piping plover, and interior least tern consists of crustaceans, mollusks, fly larvae, beetles, and small fish (interior least terns depend heavily on cyprinids) (NatureServe 2014f; Stucker et al. 2012; USFWS 2013a). Whooping cranes are omnivorous and consume a broad array of foods, including crustaceans (e.g., blue crabs [*Callinectes sapidus*], clams [*Tagellus plebius*], crayfish [*Cambarus hedgepethi*]), small fish, insects, amphibians, reptiles, grains, marsh plants, and acorns (Hunt and Slack 1989; NatureServe 2014e). See Specific Taxa Literature section for specific prey.

B.2 Selenium analysis

Non-reproductive chronic effects in birds from Se exposure include reduced immune function, excess feather loss, liver lesions and necrosis, muscle atrophy and weight loss (Ohlendorf *et al.* 1988; Fairbrother and Fowles 1990; Ohlendorf and Heinz 2011).

The more sensitive chronic effects in birds are related to reproductive impairment. Reproductive impairment is a general term including decreased fertility, reduced egg hatchability (embryo mortality) and increased incidence of deformity in embryos including eyes, feet, legs, beak and skull (Ohlendorf and Heinz 2011). Studies on birds show that thresholds for reduced hatchability are usually below those for teratogenic effects (Ohlendorf 2003). Egg fertility in some bird species, such as American kestrel (*Falco sparverius*), is considered a more sensitive toxicological endpoint often not reported but distinct from embryotoxicity (Ohlendorf and Heinz 2011).

Egg Se concentration is the most sensitive and reliable measurement of avian Se exposure, with thresholds for reproductive impairment estimated to be between 3 and 8 μg/g, depending on the species and form of Se in the diet (Heinz 1996; Ohlendorf and Heinz 2011). It is thought that aquatic birds are more susceptible to Se toxicity than terrestrial birds species based on the lack of reproductive effects seen in meadow larks (*Sturnella neglecta*), and barn swallows (*Hirundo rustica*) studied at Kesterson Reservoir (Santolo and Ohlendorf 1994). This observation could be the result of lower exposure (different diet preferences) and/or species-specific differences in how Se is metabolised. It should be noted that sea birds are often less sensitive to Se than freshwater birds due to mechanisms thought to protect marine birds against metal toxicity (Burger *et al.* 1994).

B.3 Specific Taxa Literature Evidence Relevant to Analysis

Calidris canutus rufa, Red knot

The diet of the red knot consists of small mussels, other mollusks, and crustaceans (USFWS 2013a).

Charadrius melodus, Piping plover

The diet of the piping plover consists of worms, fly larvae, beetles, crustaceans, mollusks, and other invertebrates (NatureServe 2014d). Piping plovers are known to be "plunge-diving" piscivores and prefer slender-bodied small fish (under 52 millimeters for adults and under 34 millimeters for young chicks) (Stucker et al. 2012).

Grus Americana, Whooping crane

Whooping cranes are omnivorous and consume a broad array of foods, including crustaceans (e.g., crayfish [*Cambarus hedgepethi*]), small fish, insects, amphibians, reptiles, grains, marsh plants, and acorns (Hunt and Slack 1989; NatureServe 2014e).

Sterna antillarum athalassos, Interior least terns

Interior least terns are opportunistic piscivores, feeding on small fish or fingerlings of larger fish, and their populations depend heavily on cyprinids. They consume small fish (under 52 millimeters for adults and under 34 millimeters for young chicks), some crustaceans, and insects, which are obtained by diving from the air into shallow water (less than 4 m in depth) (NatureServe 2014f). Specific prey species include plains killifish (*Fundulus zebrinus)*, chub, shad (*Dorosoma spp.*), carps and minnows (*Cyprinidae*), freshwater drum (*Aplodinotus grunniens*), largemouth bass (*Micropterus salmoides*), white bass (*Morone chrysops*), sunfish (*Lepomis spp.*), top minnows (*Fundulus spp.*), silver and bighead carp (*Hypophthalmichthys spp.*), emerald shiner (*Notropis atherinoides*), sand shiner (*Notropis stramineus*), red shiner (*Cyprinella lutrensis)*, spotfin shiner (*Cyprinella spiloptera*), bigmouth buffalo (*Ictiobus cyprinellus*), western mosquitofish (*Gambusia affinis)*, channel catfish (*Ictalurus punctatus)*, orangespotted sunfish (*Lepomis humilis*), and inland silverside (*Menidia beryllina*) (Schweitzer and Leslie 1996; Stucker et al. 2012; USFWS 2013b).

C. Fish

Crystallaria cincotta, Diamond darter
Etheostoma chienense, Relict darter
Etheostoma percnurum, Duskytail darter
Etheostoma susanae, Cumberland darter
Notropis albizonatus, Palezone shiner
Phoxinus cumberlandensis, Blackside dace
Scaphirhynchus albus, Pallid sturgeon
Scaphirhynchus platorynchus, Shovelnose sturgeon

C.1 General analysis

Eight fish species are considered in this evaluation, representing five genera (*Etheostoma, Notropis, Phoxinus, Scaphirhynchus* and *Crystallaria*). Human activities such as impoundments, channelization of rivers and streams, removal of riparian vegetation, commercial fishing, poor land-use practices, drainage of riparian wetlands, pollutants from municipal wastewater plants, resource extraction activities (e.g., coal mining), and agricultural practices have negative impacts on those species. These activities result in habitat fragmentation and lead to low species abundance, which make populations more vulnerable to effects of habitat modification, siltation, chemical spills, and nonpoint source pollution, which can lead to extirpation (Bennett 2003; Kuhajda et al. 2009; Piller and Burr 1999; USFWS 2013c; 58 FR 25758, April 27, 1993).

C.2 Selenium Analysis

Selenium is a naturally occurring chemical element that is also an essential micronutrient. Trace amounts of selenium are required for normal cellular function in almost all animals. However, excessive amounts of selenium can also have toxic effects, with selenium being one of the most toxic of the biologically essential elements (Chapman et al. 2010). Egg-laying vertebrates have a lower tolerance than do mammals, and the transition from levels of selenium that are biologically essential to those that are toxic occurs across a relatively narrow range of exposure concentrations (Luckey and Venugopal 1977; USEPA 1987, 1998; Haygarth 1994; Chapman et al. 2009, 2010).

Selenium is a member of the sulfur group of nonmetallic elements and consequently the two chemicals share similar characteristics. Selenium can replace sulfur in two amino acids, the seleno-forms being selenomethionine and selenocysteine. It has been a long-standing hypothesis that the cause of malformations in egg-laying vertebrates is due to the substitution of selenium for sulfur in these amino acids and their subsequent incorporation into proteins causing disruption of the structure and function of the protein. When present in excessive amounts, selenium is erroneously substituted for sulfur, resulting in the formation of a triselenium linkage (Se-Se-Se) or a selenotrisulfide linkage (S-Se-S), either of which was thought to prevent the formation of the normal disulfide chemical bonds (S-S). The end result was thought to be distorted, dysfunctional enzymes and protein molecules that impaired normal cellular biochemistry (Diplock and Hoekstra 1976; Reddy and Massaro 1983; Sunde 1984).

Recent research, however, suggests that selenium's role in oxidative stress plays a role in embryo toxicity, whereas selenium substitution for sulfur does not. The substitution of selenomethionine for methionine does not appear to affect either the structure or function of proteins (Yuan et al. 1998; Mechaly et al. 2000; Egerer-Sieber et al. 2006). The reason is apparently due to selenium not being distally located in selenomethionine and therefore its effect on the tertiary structure of the protein is insulated. Although the incorporation of selenomethionine into proteins is concentration-dependent (Schrauzer 2000), selenocysteine's incorporation into proteins is not (Stadtman 1996). This suggests that neither selenomethionine nor selenocysteine affect protein structure or function. In fact, Se as an essential micronutrient is incorporated into functional and structural proteins as selenocysteine.

The role of selenium-induced oxidative stress in embryo toxicity and teratogenesis appears to be related to glutathione homeostasis. A review of bird studies by Hoffman (2002) showed exposure to selenium altered concentrations and ratios of reduced to oxidized glutathione thereby increasing measurements of oxidative cell damage. Palace et al. (2004) suggested oxidative stress due to elevated selenium levels results in pericardial and yolk sac edema in rainbow trout embryos. Evidence for the role of oxidative stress in selenium toxicity is growing but mechanistic studies are needed to better understand its effects on egg-laying vertebrates. For a more in depth discussion on the mechanism of toxicity at the cellular level including the evidence against sulfur substitution as a cause and the role of oxidative stress see Janz et al. (2010).

The most well-documented, overt and severe toxic symptoms in fish are reproductive teratogenesis and larval mortality. Egg-laying vertebrates appear to be the most sensitive taxa, with toxicity resulting from maternal transfer to eggs. Selenium consumed in the diet of adult female fish is deposited in the eggs, when selenium replaces sulfur in vitellogenin, which is transported to the ovary and incorporated into the developing ovarian follicle (Janz et al. 2010), the primary yolk precursor. In studies involving young organisms exposed through transfer of selenium from adult female fish into their eggs, the most sensitive diagnostic indicators of selenium toxicity in vertebrates occur when developing embryos metabolize organic selenium that is present in egg albumen or yolk. It is then further metabolized by larval fish after hatching.

A variety of lethal and sublethal deformities can occur in the developing fish exposed to selenium, affecting both hard and soft tissues (Lemly 1993b). Developmental malformations are among the most conspicuous and diagnostic symptoms of chronic selenium poisoning in fish. Terata are permanent biomarkers of toxicity, and have been used to identify impacts of selenium on fish populations (Maier and Knight 1994; Lemly 1997b). Deformities in fish that affect feeding or respiration can be lethal shortly after hatching. Terata that are not directly lethal, but distort the spine and fins, can reduce swimming ability and overall fitness. Because the rate of survival of deformed young would be less than that for normal young, the percentage of deformed adults observed during biosurveys will likely understate the underlying percentage of deformed young, although quantitation of the difference is ordinarily not possible.

In summary, the most sensitive indicators of selenium toxicity in fish larvae are effects modulated through the reproductive process and exhibited in fish larvae as teratogenic deformities such as skeletal, craniofacial, and fin deformities, and various forms of edema that result in mortality (Lemly 2002). The toxic effect generally evaluated is the reduction in the number of normal healthy offspring compared against the starting number of eggs. In studies of young organisms exposed to selenium solely through their own diet (rather than via maternal transfer), reductions in survival and/or growth are the effects that are generally evaluated.

C.3 Specific Taxa Literature Evidence Relevant to Analysis

Crystallaria cincotta, Diamond darter

Feeding habits of the diamond darter in the wild are not known; however, based on studies of crystal darters, adult diamond darters are benthic invertivores. Related crystal darters eat midge and caddisfly larvae, and water mites; and juvenile and young eat immature stages of aquatic insects such as mayflies, craneflies, blackflies, caddisflies, and midges as well as zooplankton prey (78 FR 52364, August 22, 2013).

Etheostoma chienense, Relict darter

Relict darter prey are thought to consist mainly of aquatic insects and small crustaceans (NatureServe 2014g).

Etheostoma percnurum, Duskytail darter

Duskytail darters are known to be insectivores, and diets consist mainly of microcrustaceans, chironomid larvae, and heptageniid mayfly nymphs (*Stenonema* and *Stenacron*) (Layman 1991).

Etheostoma susanae, Cumberland darter

In general, there is limited information about the feeding habits of the Cumberland darter, but they are likely to be similar to its related species, the Johnny darter (*Etheostoma nigrum*). Johnny darters are diurnal sight feeders that feed on prey including midge larvae, mayfly nymphs, caddisfly larvae, and microcrustaceans. Juveniles likely feed on planktonic organisms and other small invertebrates like other darters (77 FR 63604, October 16, 2012).

Notropis albizonatus, Palezone shiner

Palezone shiners prefer dipteran larvae in the suborder Nematocera as well as other aquatic organisms such as small crustaceans, roundworms, aquatic mites, diatoms, and some plant material (USFWS 2013c).

Phoxinus cumberlandensis, Blackside dace

Blackside dace feed on organic detritus, periphyton (diatoms and other algae), and invertebrates (e.g., Chironomidae and Hydropsychidae) (NatureServe 2014i; Starnes and Starnes 1981).

Scaphirhynchus albus, Pallid sturgeon

Pallid sturgeon are known to feed opportunistically on aquatic insects, crustaceans, mollusks, annelids, eggs of other fishes, and other fish (Hoover et al. 2007; NatureServe 2014j). The diet of the pallid sturgeon appears to shift from macroinvertebrates to fish over time, although the exact timing and at what life stage of the sturgeon it happens is unknown (Grohs et al. 2009; USFWS 2014b; Wildhaber et al. 2011). A stomach content analysis of pallid sturgeon identified fish (Cyprinidae and Ictaluridae), aquatic insects (Diptera, Ephemeroptera, Odonata, Plecoptera, and Trichoptera), copepods, leeches, and mussels (Winders et al. 2014). Other diet composition studies of the pallid sturgeon found similar prey: Ephemeroptera (especially Isonychiidae), dipterans (Ceratopogonidae and Chironomidae), odonates, isopods, decapods, and fishes (Grohs et al. 2009; Wanner and Shuman 2007).

Based on a small study examining the growth and diet of released embryo and larvae of the pallid sturgeon, gut contents contained Diptera larvae and pupae and Ephemeroptera nymphs (Braaten et al. 2012).

Diets for age-0 pallid sturgeon were dominated by midge larvae (Chironomidae) and mayflies (Ephemeroptera). Midges were preferred over mayflies. They are also known to feed on dipteran pupae (Sechler et al. 2012). A study that looked at prey consumed by pallid sturgeon young-of-year found that 64 percent of the prey belonged to a single subgroup of Chironomidae (Diptera: Chironominae: Hamischia complex) of which several genera, including *Chemovskiia, Cryptochironomus, Gillotia, Paracladopetma, Robackia*, and *Saetheria*, are known to be primary inhabitants of sandy benthos and channel habitats (Harrison et al 2014).

Primary prey for age-6 and age-7 of pallid sturgeons were fish, including sturgeon chub (*Macrhybopsis gelida*) and sicklefin chub (*M. meeki*), channel catfish (*Ictalurus punctatus*), flathead chub (*Platygobio gracilis*), sand shiner (*Notropis stramineus*), and shorthead redhorse (*Moxostoma macrolepidotum*) (Gerrity et al. 2006).

Scaphirhynchus platorynchus, Shovelnose sturgeon

Shovelnose sturgeon feed mostly on bottom-dwelling immature aquatic insects and other benthic invertebrates, and fish eggs (NatureServe 2014k). Primary prey for shovelnose sturgeons were found to be aquatic insect larvae and nymphs, especially Diptera, Ephemeroptera, and Trichoptera (Gerrity et al. 2006; Hoover et al. 2007). Diptera of the family Chironomidae were dominant prey (mostly represented by four genera: *Paracladopelma*, *Chernovskiia*, *Saetheria* and *Robackia*), in addition to Ephemeroptera of the families Isonychiidae and Caenidae, as well as Trichoptera of the family Hydropsychidae (Rapp et al. 2011).

Based on a stomach content study conducted on the shovelnose sturgeon, approximately 48 and 36 percent composition by weight of prey were fish and Chironomidae, respectively, in one year, then 73 percent Ephemeroptera and 3 percent fish, respectively, in another. Other prey found in the stomach included Odonata, Isopoda, Johnny darter (*Etheostoma nigrum*), and emerald shiner (*Notropis atherinoides*) (USEPA 2007a). Diets of the shovelnose sturgeon can change throughout the year with spring diets consisting mostly of Chironomidae larvae, and autumn diets consisting mostly of Hydropsychidae larvae (Bock et al. 2011).

Diets for age-0 shovelnose sturgeon were dominated by midge larvae (Chironomidae) and mayflies (Ephemeroptera). Midges were preferred over mayflies. They are also known to feed on dipteran pupae (Sechler et al. 2012).

D. Crustaceans *Palaemonias ganteri*, Kentucky cave shrimp

D.1 General analysis

Freshwater atyid shrimp are relatively rare in North America, the Kentucky cave shrimp being one of three species known north of Mexico. This species has been found only within the Mammoth Cave National Park. Its critical habitat is the Roaring River, but individuals have been found at several other locations within the park.

The Kentucky cave shrimp is a subterranean obligate, found in pools with silty bottoms. It is a detritivore and feeds on "protozoans, algal cells, fungi, and other organic materials." The species has very specific habitat requirements - large, base level passages of caves characterized by slow flow, abundant organic matter, and coarse to fine grain sand and coarse silt sediments (http://ecos.fws.gov/docs/five_year_review/doc3203.pdf).

Threats occur from: traffic accidents; oil and gas operations; agricultural activities in which the primary concerns are sediment, nutrients and pesticides; stormwater runoff and septic system discharges in which the primary concern is bacteria; and impoundments in which the primary concern is sediment.

Pollution of local groundwater by sewage and of the Green River by oil brines and hydrocarbons during the 1960s entered base level cave streams. Modifications of habitat and flooding regimes caused by dams in the Green River basin also adversely affected the shrimp by reducing its reproductive success and increasing its predation pressure (Lisowski 1983).

Heterotrophs populating the cave system depend on food imported to the system through trogloxenes, accidentals and nutrient-laden water; any event that affects the groundwater basin will have a direct impact on the species; food supply is limited and dependent upon natural phenomena, and highly susceptible to perturbations. The shrimp is threatened by contamination of groundwater from inadequate sewage treatment (Leitheuser 1988).

Groundwater contamination represents the greatest threat to the Kentucky cave shrimp (USFWS 1988). Sources of this contamination include random traffic accidents (*e.g.*, trucks carrying toxic chemicals) along Interstate 65 (I-65) and other local highways; oil and gas activities; agriculture; permitted discharges from industry, wastewater treatment plants, and other sources; and general nonpoint-source pollution (USFWS 1988). Because of the extensive karst systems in the Mammoth Cave region, pollutants associated with these contaminant sources can quickly enter groundwater basins through sinkholes, sinking streams, and other karst features and travel rapidly downstream to where they can adversely affect cave shrimp populations.

D.2 Specific Taxa Literature Evidence Relevant to Analysis

Palaemonias ganteri, Kentucky cave shrimp

This taxon is known to inhabit underground streams - typically large, base level cave streams characterized by slow flow, abundant organic material, coarse to fine grain sand, and coarse silt sediments. A review of available toxicology information revealed very limited data on the effects of selenium on crustaceans; however, limited in situ testing indicates that crustaceans are not affected, either short term or long term, by exposures up to 25 µg/L. Additionally, the only genus of concern (*Palaemonias*) and its critical habitat is not in a location that would generally be expected to experience elevated selenium levels in the environment.

E. Freshwater mussels

Alasmidonta atropurpurea, Cumberland elktoe
Cumberlandia monodonta, Spectaclecase
Cyprogenia stegaria, Fanshell
Dromus dromas, Dromedary pearlymussel
Epioblasma brevidens, Cumberlandian combshell
Epioblasma capsaeformis, Oyster mussel
Epioblasma florentina walkeri, Tan riffleshell
Epioblasma obliquata obliquata, Catspaw
Epioblasma torulosa rangiana, Northern riffleshell
Epioblasma triquetra, Snuffbox
Hemistena lata, Cracking pearlymussel
Lampsilis abrupta, Pink mucket
Leptodea leptodon, Scaleshell
Obovaria retusa, Ring pink
Pegias fabula, Littlewing pearlymussel
Plethobasus cicatricosus, White wartyback
Plethobasus cooperianus, Orangefoot pimpleback
Plethobasus cyphyus, Sheepnose
Pleurobema clava, Clubshell
Pleurobema plenum, Rough pigtoe
Pleuronaia dolabelloides, Slabside pearlymussel
Potamilus capax, Fat pocketbook
Ptychobranchus subtentum, Fluted kidneyshell
Quadrula cylindrica cylindrical, Rabbitsfoot
Quadrula fragosa, Winged mapleleaf
Villosa trabalis, Cumberland bean

E.1 General analysis

There are 26 federally listed species of freshwater mussels being evaluated. The large number of listed species reflects the general imperilment of this taxonomic group, the most imperiled freshwater organisms in the United States (Cope et al. 2008).

Freshwater mussels are filter feeding, benthic bivalve mollusks that feed on detritus, diatoms, phytoplankton, and zooplankton (Parmalee and Bogan 1998). The juveniles and adults live burrowed in the substrate of permanent water bodies and use a set of siphons to inhale water through their gills, with which they filter food and breathe (McMahon and Bogan 2001). Freshwater mussels are generally gonochoristic (two distinct sexes), although some taxa are hermaphroditic. Almost all taxa are ovoviviparous and brood their developing embryos in special modified gill marsupia. They release their fully formed larvae (glochidia) into the water. In unionid mussels, represented by the taxa above, the glochidia are obligately parasitic on specific host fish species. They encyst on the host and complete development while being dispersed by the host before final metamorphosis into juveniles, which settle on the bottom of the stream, burrow into the substrate, and develop into adults. Many species release glochidia in special conglutinates (many glochidia contained within a mucosal sac). Some representative species have elaborately developed conglutinates or superconglutinates that mimic insect or fish prey and lure host fish into consuming them, after which the glochidia attach to the fish gills or skin (McMahon and Bogan 2001). Even so, larval mortality is extremely high and most populations grow very slowly.

Freshwater mussel habitat requirements vary. They inhabit small-to-medium-sized streams (e.g., little pearlymussel, oyster mussel) to very large rivers (e.g., catspaw, slabside pearlymussel, spectaclecase) (Butler and Biggins 2004; Cummings and Cordeiro 2012; NatureServe 2014l; 77 FR 60804, October 4, 2012; 78 FR 57076, September 17, 2013). They generally require reaches with sand/gravel to cobble-size substrates, predominantly in riffle/run geomorphic units with substantial flow (e.g., Cumberlandian combshell, dromedary pearlymussel, fluted and triangular kidneyshells, and snuffbox) (Ahlstedt 1983; Butler and Biggins 2004; USFS 2006; Zanatta and Murphy 2008). Some species, however, prefer mud/sandy substrates (e.g., cracking pearlymussel, pink mucket) (USFWS 1997a, 1997b) and even slower moving reaches (e.g., Cumberland elktoe) (NatureServe 2014m). They generally require well-oxygenated waters; for example, the slabside pearlymussel, and the fluted kidneyshells are intolerant of dissolved oxygen below mg/L (Grabarkiewicz and Davis 2008; USFS 2006; 77 FR 60804, October 4, 2012; 78 FR 57076, September 17, 2013).

These mussels, in general, live embedded in the bottom sand, gravel, and/or cobble substrates of rivers and streams. They also have a unique life cycle that involves a parasitic stage on host fish. Juvenile mussels require stable substrates with low to moderate amounts of sediment and low amounts of filamentous algae, and correct flow and water quality to continue to develop. The presence of suitable host fish is considered an essential element in these mussels' life cycles. In addition, because of their life cycle, small population sizes, and limited habitat availability, they are highly susceptible to competitive or predaceous nonnative species (69 FR 53147).

In the late 1800s and early 1900s mussels were heavily harvested on larger rivers to supply the button industry and also in the quest for pearls, until populations became severely depleted and states were forced to adopt harvest regulations (USFWS 2003). More recently, freshwater navigation facilities, dredging for channel maintenance, sand and gravel mining, the proliferation of the exotic zebra mussel (Dreissena polymorpha) in areas inhabited by native mussels, sedimentation, and water pollution, including both point and nonpoint sources of pollution (USFWS 2003) have caused a decline in native mussels. Relatively little information is known about the specific habitat associations, food sources and reproductive biology of endangered unionid mussels.

E.2 Selenium analysis

As stated earlier, the most sensitive mode of action and outcome from selenium exposure are skeletal deformities in oviparous vertebrates i.e., fish. Mussels contain no skeletal structure which would be affected by selenium. Because the most relevant and sensitive enpoint was skeletal deformities in oviparous vertebrate, no data for mussels were used in the development of the Commonwealth's chronic selenium criterion. A review of available toxicology information revealed very limited data on the effects of selenium on mussels; however, limited testing indicates that mussels are not affected, either short term or long term, by exposures up to 400 µg/L with the exception of one reported LOEC at 100 µg/L for zebra mussel valve closure. Additionally, invertebrate data from EPA's recent draft selenium criterion did not indicate effects at either the 5.0 µg/L trigger level or the 20 µg/L acute criterion in Kentucky.

Some listed mussel species are known to have a life cycle which depends on fish species as an intermediate host. Typically, the intermediate hosts are from the genera that include stonerollers, darters and shiners i.e., *Notropis* and *Etheostoma*. As previously outlined, the toxicological profiles of these genera do not indicate that these genera will be adversely affected by selenium.

XI. Effects Determinations

A. Selenium in general

The value of Kentucky's chronic whole body fish tissue selenium criterion falls within ranges that protect aquatic life against the harmful effects of selenium and is scientifically defensible and expected to be protective of the designated use. The fish data used by the Commonwealth were sufficient and relevant to support the criterion, and the derivation of the criterion was consistent with the EPA's own approach as outlined in EPA's 1985 guidelines.

In addition, a fish tissue based value is more indicative of determining effects in aquatic life than a water column value because of the variability that exists with rates of uptake of dissolved selenium by plant life and trophic transfer factors among waterbodies. The same water column concentration could produce a fish tissue concentration within a two order of magnitude range of values, depending on the characteristics of the individual water. This is because, at the base of the food web, algae and other microorganisms accumulate selenium from water by factors ranging from several hundred to tens of thousands (Luoma and Presser 2009; Orr et al. 2012; Stewart et al. 2010). As such, traditional methods for predicting toxicity on the basis of exposure to dissolved [water column] concentrations do not work for selenium because the behavior and toxicity of selenium in aquatic systems are highly dependent upon site-specific factors, including food web structure and hydrology. Thus, it is more accurate to rely on measures of selenium in fish tissue than measures of selenium in the water column to determine potential effects and protective levels for aquatic life in general, and also for proposed, threatened, and endangered species.

B. Bats

Critical habitat is not an issue in analyzing these species since only one of them (*Myotis sodalis*) has critical habitat designated and the approved action is unlikely to alter this critical habitat (see page 16).

B.1 Selenium Determination

As noted earlier, mammals are generally highly tolerant to selenium, especially compared to oviparous vertebrates. We are not aware of any selenium toxicity studies with bats or similar mammals. Sublethal liver changes have been found in laboratory rats (*Rattus norvegicus*) following lifetime exposure to natural selenium in the diet at a concentration of 1.4 µg/g (dry weight) and reduced longevity was found at 3 µg/g in the lifetime diet (Eisler 1985). Olson (1986) also reported reproductive selenosis in rats that consumed wheat with a concentration of 3 µg/g. Halverson *et al*. (1966) found a dietary selenium threshold of about 4.8 µg/g for growth retardation in rats. Given the bioaccumulative nature of selenium and the selenium criterion in fish tissue being considered here (8.6 µg/g), concentrations in insect tissue should be substantially below those reported here to cause effects in rats due to lifetime dietary exposure. Based on these considerations, the EPA-approved changes to the selenium criterion are **not likely to adversely affect** the four bat populations considered in this evaluation

C. Birds

There are no critical habitat requirements, including PCEs, for these bird species. Three of the four species are migratory, while the interior least tern appears to be most susceptible to habitat change related to the availability of preferred nesting sites and prey availability. Habitat loss (nesting, migration and wintering grounds) and limited genetic viability continue to be the major threats to the eastern migratory population of whooping cranes.

These changes are often the result of physical human activities such as the modification of river flow (e.g., damming), channelization, and bank stabilization, which are not related directly to nutrient inputs. We are not aware of any selenium toxicity studies with interior least terns.

C.1 Selenium Determination

The interior least tern primarily occupies island/sandbars within the main stem of the Ohio River in the western areas of Kentucky during the nesting and breeding season. A 2005 survey counted 172 adult interior least terns and 7 colonies along the Ohio River (Lott 2006). The primary route of possible exposure to selenium would be through food items (*Notropis* sp., shad, stonerollers and other small fishes). EPA's 2008-2009 National Rivers and Streams Assessment contains fish tissue data for selenium in sections of the Ohio River in Kentucky (USEPA 2013). These data indicate that concentration of selenium in sampled fish (largemouth bass, white bass, spotted bass and sauger) was not greater than 3mg/kg dw. Using trophic transfer factors to estimate the level in trophic level 2 fish, EPA estimates that the concentration in the prey base for the interior least tern will be no greater than 1.5mg/kg dw. This indicates that fish sources are likely to be low in selenium, and would not impact least terns breeding in the Ohio River. Additionally, USFWS has reported that the least tern typically forages for food within 7 miles of the nesting site.[13] Due to the geographic restrictions of the least tern's forage area, the species of fish upon which the least tern feeds and the low levels of selenium reported in fish in the Ohio River, it is unlikely that the least tern will be exposed to selenium levels of concern.

The other three endangered or threatened bird species do not nest in Kentucky and and body burden of selenium ingested during migration is expected to be minimal. As such, EPA has determined that the approval of the selenium criterion is **not likely to adversely affect** these four endangered or threatened bird species in Kentucky.

D. Fish

Of the eight endangered fish species addressed in this BE, USFWS has designated critical habitat for the diamond darter and the Cumberland darter and identified physical or biological features essential to the conservation of the two species. USFWS has listed PCEs, which are specific elements of the physical or biological features that provide for the species' life-history processes and are essential to the conservation of the species. Key PCE elements for both the diamond and Cumberland darters are geomorphically stable streams, stable stream bottom substrates, sufficient instream flow regime, adequate water quality, and habitats allowing for an adequate prey base. Adequate water quality is characterized by moderate stream temperatures, acceptable dissolved oxygen concentrations, moderate pH, and low levels of pollutants, and provides the quality necessary for normal behavior, growth, and viability of all life stages of both the diamond darter and the Cumberland darter (77 FR 63604, October 16, 2012; 78 FR 52364, August 22, 2013). Habitats must accommodate foraging, breeding, growth, and migration during various life stages of all eight species. In addition, habitats should support the physical, chemical, and biological conditions necessary for the survival of their prey. Habitat features essential to these taxa include good water quality, clean and stable substrates (i.e., silt-free), and healthy benthic invertebrate populations (77 FR 63604, October 16, 2012; 78 FR 52364, August 22, 2013).

The impoundments of rivers in the Ohio River Basin, such as the Kanawha, Ohio and Cumberland, have eliminated much of the species' habitat and isolated the existing population from other watersheds that the species historically occupied (Welsh et al. 2009). The diamond darter was last collected in Kentucky in 1929 (Burr and Warren 1986) and in Tennessee in 1939 (Etnier and Starnes 1993).

Habitat fragmentation increases the risk of genetic isolation, leaves reduced space for rearing and reproduction, and increases the likelihood of local extinctions, thus the connectivity of habitats is essential to the survival of these species (77 FR 63604, October 16, 2012). Siltation, impoundment, and coal mining are identified as the major threats to the eight species. The most significant of these impacts is siltation (excess sediments suspended or deposited in a stream) caused by excessive releases of sediment from activities such as resource extraction (e.g., coal mining, silviculture, natural gas development), agriculture, road construction, and urban development (Waters 1995, pp. 2-3; Skelton 1997, pp. 17, 19; KDOW 2006, pp. 178-185;

[13] http://www/fws/gov/southeast/5yearReviews/5yearreviews/interiorLeastTern5yrReview102413.pdf

Thomas 2007, p. 5, 77 FR 63604, October 6, 2012). Siltation contributes to turbidity of the water and has been shown to reduce photosynthesis in aquatic plants, suffocate aquatic insects, smother fish eggs, clog fish gills, and may fill in essential interstitial spaces (spaces between stream substrates) used by aquatic organisms for spawning and foraging; therefore, excessive siltation negatively impacts fish growth, physiology, behavior, reproduction, and survival (77 FR 63604, October 6, 2012). The diamond darter and the Cumberland darter are known to be particularly susceptible to siltation (Bennett 2003; USFWS 2013c; 58 FR 25758, April 27, 1993; 77 FR 63604, October 16, 2012; 78 FR 52364, August 22, 2013).

The diamond darter has been extirpated from all of the Kentucky streams and is now known to occur only within the lower Elk River in West Virginia.

D.1 Selenium Determination

Diamond darter	*Crystallaria cincotta*
Relict darter	*Etheostoma chienense*
Duskytail darter	*Etheostoma percnurum*
Cumberland darter	*Etheostoma susanae*

Based on taxonomic and habitat relationships, the appropriate surrogates for *Etheostoma* and *Crystallaria* are *Micropterus* and *Lepomis* (both are from the Order Perciformes). The reported toxicological value in Kentucky's database for *Micropterus* is 11 mg Se/kg dry weight (dw) in whole body which is associated with an EC_{10} for the effect of larval mortality as reported by CP&L 1997. *Lepomis macrochirus* is the most sensitive species in the Kentucky dataset with a reported genus mean chronic value (GMCV) in whole body of 8.9 mg/kg dw. This value is greater than the chronic value adopted by Kentucky of 8.6 mg Se/kgdw whole body. EPA's database and subsequent analyses produced a GMCV of 8.41 mg Se/kg dw whole body for the genus *Lepomis*. Although this GMCV lies slightly below the Kentucky adopted criterion value, EPA believes it provides essentially the same level of protection taking into consideration factors such as the analytical precision of measurements of selenium in fish tissue, the likely lack of signifigance of the incremental toxicological effects of a difference of 0.2 mg Se/kg dw whole body fish tissue, and the typical efforts made by regulators and permit holders to ensure selenium levels are well below established limits to ensure compliance In light of the above information, EPA believes that Kentucky's adopted criterion are protective of the listed darter species above.

Palezone shiner	*Notropis albizonatus*
Blackside dace	*Phoxinus cumberlandensis*

Based on taxonomic and habitat relationships, the appropriate surrogate for *Notropis* and *Phoxinus* is *Pimephales* (related at the Family level). The toxicological values reported in Kentucky's database resulted in a GMCV of 31 mg Se/kg dw in whole body (Schultz and Hermanutz 1990, GEI 2008). This value is substantially greater than the chronic whole body value adopted by Kentucky. EPA's database and analyses resulted in a GMCV of 11.94 mg Se/kg dw in whole body for *Pimephales* which is still greater than Kentucky's adopted whole body criterion. Also, a review of field data from a number of selenium impacted waters in the western US has shown substantively diverse cyprinid populations, further indicating that cyprinids, as a Family, are not sensitive to selenium toxicity (Barwick and Harrel 1997, Canton 2010, Crutchfield Jr. 2000, Hamilton et. Al. 2000, May and Walther 2012, NAMC 2008, Presser 2013, USGS 2011). EPA believes that Kentucky's adopted criterion are protective of the listed dace and shiner species above.

Pallid sturgeon	*Scaphirhynchus albus*
Shovelnose sturgeon	*Scaphirhynchus platorynchus*

Based on taxonomic and habitat relationships, the appropriate surrogate for *Scaphirhynchus* is *Acipenser* (related at the Family level). The toxicological value used in Kentucky's database was15 mg Se/kg dw in whole body(Tashijian 2006). This value is substantially greater than the chronic whole body value adopted by Kentucky. Recently, additional data have become available that indicate a lower value of 16.27 mg/kg for ovary/egg tissue which would subsequently lower the whole body value after translation (Linville 2006). Because the Tashijian study uses a different endpoint from the Linville study, these two studies cannot be averaged. EPA's analysis of the Linville study results in a GMCV of 9.60 mg Se/kg dw whole body for *Acipenser*, which is greater than Kentucky's adopted whole body criterion.

Additionaly, EPA believes there is general lack of exposure in Kentucky since sturgeon and their critical habitat are not located within the watersheds affected or potentially affected by selenium. Shovelnose sturgeon habitat goes up the Ohio River along the Western coal field counties, some of whose waters may discharge into the Ohio River. As indicated in the selenium determination for birds previously, data from the upstream Ohio River basin by the Ohio EPA, showed 6000 samples from approximately 30 years where only 6 of those samples exceeded the selenium whole body criterion indicating a low potential for selenium risk to shovelnose sturgeon.

Because both sturgeon are primarily found in the main stem of the Ohio River and based on the data presented above, EPA believes that it is unlikely that selenium mobilized from the Western coal fields will reach the Ohio River in concentrations that approach those necessary to affect either sturgeon species.

The proposed concentration of selenium in fish tissue is considered to be at a level below which there would not likely be any adverse effects. The EPA concludes that the chronic selenium criterion adopted by the Commonwealth is **not likely to adversely affect** listed fish in Kentucky.

E. Crustaceans - Kentucky cave shrimp

Critical habitat PCE requirements were not included with the *Federal Register* notice for the Kentucky cave shrimp and were, therefore, inferred from the text (45 FR 68975, October 17, 1980; 48 FR 46337, October 12, 1983). These habitat elements include streams in base-level cave passages with seasonally quiet pools, abundant quantities of organic matter, and coarse silt-to-very coarse-to-very fine sands (DeGrave and Rogers 2013). Other evidence suggests the species may be able to breed outside of the quiet pool habitat (48 FR 46337, October 12, 1983).

This species is a collector-gatherer invertebrate that appears to feed primarily on detrital material from a variety of primarily allochthonous sources.

E.1 Selenium Determination

As stated earlier, the most sensitive mode of action and outcome from selenium exposure are skeletal deformities in oviparous vertebrates i.e., fish. Crustaceans contain no skeletal structure which would be affected by selenium. No data for crustaceans were considered in the development of the Commonwealth's chronic criterion. A review of available toxicology information revealed very limited data on the effects of selenium on crustaceans; however, limited in situ testing indicates that crustaceans are not affected, either short term or long term, by exposures up to 25 µg/L (Crane et al, 1992). Additionally, the only genus of concern (*Palaemonias*) and its critical habitat is not in a location that would generally be expected to experience elevated selenium levels in the environment. Based on the limit of its geographic range which is fully contained within a national park, the Kentucky cave shrimp's critical habitat is not in a location that would generally be expected to experience elevated selenium levels in the environment and future exposure is unlikely. Therefore, the EPA has determined that Kentucky's aquatic life chronic criterion for selenium is **not likely to adversely affect** the Kentucky cave shrimp.

F. Mussels

Mussel populations throughout the Central and Eastern United States have been declining since modern civilization began to significantly alter aquatic habitats. The Ohio River drainage, which includes the Tennessee and Cumberland rivers, was a center for freshwater mussel evolution and historically contained about 127 distinct mussel species and subspecies. Of this once rich mussel fauna, 11 mussels are extinct, and 33 mussels are classified as Federal endangered species. In less than 100 years, 35 percent of the Ohio River system's mussel fauna has either become extinct or federally endangered. No other wide ranging faunal group in the continental United States has experienced this degree of loss within the last 100 years.

Declines in these and other unionid freshwater mussels are attributed to a variety of factors, including:

- Impoundments and subsequent flow modifications, sediment alteration, temperature change, and impacts on host fish dispersal (Biggins 1991; Butler and Biggins 2004; Cummings and Cordeiro 2012; Jones and Neves 2002; Jones et al. 2004; USFWS 1997a, 1997b)
- Channel modification and habitat destruction/alteration from channelization, dredging, and sedimentation (Szymankski 1998;USFWS 2012a, USFWS 2014c; 77 FR 60804, October 4, 2012)
- Mining runoff including acid mine drainage and associated acidity, other toxins, and sediment (Butler and Biggins 2004; Watters 1994; 77 FR 60804, October 4, 2012)
- Land clearing and disturbance that creates erosion and sedimentation (Butler and Biggins 2004; Zanatta and Murphy 2007; 77 FR 60804, October 4, 2012)
- Invasive species (USFWS 1997c, 2009a)

- Point source discharge and nonpoint source runoff including toxins, sediment, organic enrichment, and nutrients (Davis and Layzer 2012; USFWS 2002; Strayer and Fettermen 1999; Szymanski 1998; USFWS 2012b)
- Loss of fish hosts (Bouvier et al. 2013; Miller et al. 1986; USFWS 1997b; USFWS 2014c)

The mussel fauna in most streams of the Ohio River basin have been directly impacted by impoundments, siltation, channelization, and water pollution. Reservoir construction is the most obvious cause of the loss of mussel diversity in the basin's larger rivers. Most of the main stem of both the Tennessee and Cumberland rivers and many of their tributaries are impounded. For example, over 2,300 river miles or about 20 percent of the Tennessee River and its tributaries with drainage areas of 25 square miles or greater are impounded (TVA 1971). In addition to the loss of riverine habitat within impoundments, most impoundments also seriously alter downstream aquatic habitat, and mussel populations upstream of reservoirs may be adversely affected by changes in the fish fauna essential to a mussel's reproductive cycle.

Dam construction has a secondary effect of fragmenting the ranges of aquatic mollusk species, leaving relict habitats and populations isolated by the structures as well as by extensive areas of deep uninhabitable, impounded waters. These isolated populations are unable to naturally recolonize suitable habitat that is impacted by temporary, but devastating events, such as severe drought, chemical spills, or unauthorized discharges (Layzer *et al.* 1993, pp. 68–69; Neves *et al.* 1997, pp. 63–75; Pringle *et al.* 2009, pp. 810–815; Watters 2000, pp. 264–265, 268; Watters and Flaute 2010, pp. 3–7).

Dredging and channelization activities have profoundly altered riverine habitats nationwide. Hartfield (1993, pp. 131–139), Neves *et al.* (1997, pp. 71–72), and Watters (2000, pp. 268– 269) reviewed the specific effects of channelization on freshwater mussels. Channelization impacts stream physically (for example accelerated erosion, reduced depth, decreased habitat diversity, geomorphic instability, and loss of riparian vegetation) and biologically (for example decreased fish and mussel diversity, altered species composition and abundance, decreased biomass, and reduced growth rates) (Hartfield 1993, pp. 131–139). Channel construction for navigation increases flood heights, partly as a result of a decrease in stream length and an increase in gradient (Hubbard *et al.* 1993, p. 137 (in Hartfield 1993, p. 131)). Flood events may thus be exacerbated, conveying into streams large quantities of sediment, potentially with adsorbed contaminants. Channel maintenance may result in profound impacts downstream, such as increases in turbidity and sedimentation, which may smother bottom-dwelling organisms.

Sedimentation, including siltation runoff, has been implicated as the number one factor in water quality impairment in the United States. Specific biological impacts on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills, disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity, and physical smothering. Host fish/mussel interactions may be indirectly impacted by changes in stream sediment regimes through three mechanisms: fish abundance, diversity, and reproduction reduced; impedes host fish attractant mechanisms; interfere with the ability of some species' adhesive conglutinates to adhere to rock particles. Waterborne sediment is produced by the erosion of stream banks, channels, plowed fields, unpaved roads, roadside ditches, upland gullies, and other soil disturbance sites. Agricultural activities produce the most significant amount of sediment that enters streams. Silvicultural sedimentation impacts are more the result of logging roads than the actual harvesting of timber. (NatureServe 2014)

Developmental activities associated with urbanization (e.g., highways, building construction, infrastructure creation, recreational facilities) may contribute significant amounts of sediment and other pollutants in quantities that may be detrimental to stream habitats. With development, watersheds become more impervious, resulting in increased storm-water runoff into streams and a doubling in annual flow rates in completely urbanized streams. Impervious surfaces may reduce sediment input into streams, but result in channel instability by accelerating storm-water runoff, which increases bank erosion and bed scouring (NatureServe 2014).

Coal mining-related siltation and associated toxic runoff have adversely impacted many stream reaches. Numerous streams have experienced mussel and fish kills from toxic chemical spills, and poor land-use practices have fouled many waters with silt. Runoff from large urban areas has degraded water and substrate quality. Because of the extent of habitat destruction, the overall aquatic faunal diversity in many of the basins' rivers has declined significantly. As a result of this destruction of riverine habitat, 8 fishes and 24 mussels in the Tennessee and Cumberland River basins have already required the Endangered Species Act's protection, and numerous other aquatic species in these two basins are currently considered species of concern and could warrant listing in the future.

In addition, mussels may be indirectly affected if high turbidity levels significantly reduce the amount of light available for photosynthesis and thus the production of certain food items. Studies indicate that the primary impacts of excess sediment on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box and Mosa 1999, p. 101). The physical effects of sediment on mussels are multifold, and include changes in suspended and bed material load; changes in bed sediment composition associated with increased sediment production and run-off in the watershed; changes in the form, position, and stability of channels; changes in depth or the width-to-depth ratio, which affects light penetration and flow regime; actively aggrading (filling) or degrading (scouring) channels; and changes in channel position that may leave mussels stranded (Brim Box and Mosa 1999, pp. 109–112; Vannote and Minshall 1982, p. 4106). Increased sedimentation and siltation may explain in part why spectaclecase mussels appear to be experiencing recruitment failure in some streams.

Invasive species pose an additional threat to mussels. The alien Asian clam (*Corbicula fluminea*) was first reported from the Cumberlandian Region around 1959. This species has been implicated as a competitor with native mussels for resources such as food, nutrients, and space, particularly as juveniles. Densities of Asian clams are sometimes heavy in Cumberlandian Region streams, making competition with populations of some of these five species likely. Paradoxically, large, seemingly healthy, populations of unionids may coexist with Asian clams. The invasion of the nonnative zebra mussel (*Dreissena polymorpha*) poses a threat to the mussel fauna of the Cumberlandian Region. (NatureServe, 2014)

F.1 Selenium Determination

There are 26 mussel species of concern representing 17 genera and 2 families. No data for mussels were considered in the development of the Commonwealth's chronic criterion. A review of available toxicology information revealed very limited data on the effects of selenium on mussels; however, limited testing indicates that mussels are not affected, either short term or long term, by exposures up to 400 µg/L with the exception of one reported LOEC at 100 µg/L for zebra mussel valve closure (http://www.pesticideinfo.org/List_AquireAll.jsp?Rec_Id=PC41175&Taxa_Group=Molluscs). Given that this value is above any water column value associated with Kentucky's whole fish tissue criteriont, the EPA concludes that the chronic selenium criterion adopted by the Commonwealth is **not likely to adversely affect** listed mussels in the Commonwealth.

The dromedary pearlymussel, cracking pearlymussel, Scaleshell, white wartyback, slabside pearlymussel and winged mapleleaf may be extirpated from Kentucky. These species have not been observed in Kentucky for over 20 years (December 11, 2014 letter from FWS). Although the habitat for these species is present, EPA concluded that a **No Effect** determination is appropriate for these species.

XII. Conclusion

Our research has shown that the most significant threats to all the species in Kentucky that are proposed, threatened and endangered are habitat loss and degradation associated with various kinds of human activities, such as development, impoundments, stream channelization, siltation caused by poor land use practices, logging, and oil, gas and mineral development. This biological evaluation analyzes the potential effects of EPA's action on threatened and endangered species and designated critical habitat by the approval of the Kentucky's whole body selenium criterion within their water quality standards. EPA has found that the approval of the whole body chronic aquatic life criterion for selenium is not likely to lead to adverse effects.

The action to approve Kentucky's chronic whole body selenium criterion will have **No Effect** on the designated CH of the Indiana bat, Braun's rockcress, Kentucky glade cress, Short's bladderpod because the upland habit areas designated as CH for these plant specis are not aquatic habitats and the action is unlikely to result in any alteration of these CH areas that would result in the adverse modification of the CH (USFWS December 11, 2014).

The EPA's analysis indicates that the approval of the chronic whole body criterion for selenium are **not likely to adversely affect** the proposed, threatened and endangered species in the Commonwealth of Kentucky as listed below.

<u>Bats</u>
Corynorhinus (=plecotus) townsendii virginianus, Virginia big-eared bat
Myotis grisescens, Gray bat
Myotis septentrionalis, Northern long-eared bat
Myotis sodalis, Indiana bat

Birds
Calidris canutus rufa, Red knot (migrant only)
Charadrius melodus, Piping plover (migrant only)
Grus Americana, Whooping crane (migrant only)
Sterna antillarum athalassos, Interior least tern

Fish
Crystallaria cincotta, Diamond darter
Etheostoma chienense, Relict darter
Etheostoma percnurum, Duskytail darter
Etheostoma susanae, Cumberland darter
Notropis albizonatus, Palezone shiner
Phoxinus cumberlandensis, Blackside dace
Scaphirhynchus albus, Pallid sturgeon
Scaphirhynchus platorynchus, Shovelnose sturgeon

Crustaceans
Palaemonias ganteri, Kentucky cave shrimp

Freshwater mussels
Alasmidonta atropurpurea, Cumberland elktoe
Cumberlandia monodonta, Spectaclecase
Cyprogenia stegaria, Fanshell
Epioblasma brevidens, Cumberlandian combshell
Epioblasma capsaeformis, Oyster mussel
Epioblasma florentina walkeri, Tan riffleshell
Epioblasma obliquata obliquata, Catspaw
Epioblasma torulosa rangiana, Northern riffleshell
Epioblasma triquetra, Snuffbox
Lampsilis abrupta, Pink mucket
Obovaria retusa, Ring pink
Pegias fabula, Littlewing pearlymussel
Plethobasus cooperianus, Orangefoot pimpleback
Plethobasus cyphyus, Sheepnose
Pleurobema clava, Clubshell
Pleurobema plenum, Rough pigtoe
Potamilus capax, Fat pocketbook
Ptychobranchus subtentum, Fluted kidneyshell
Quadrula cylindrica cylindrical, Rabbitsfoot
Villosa trabalis, Cumberland bean

EPA has also concluded that an EPA action to approve the primacy of fish tissue criterion elements over water column criterion elements **is not likely to adversely affect** the proposed, threatened and endangered species in the Commonwealth of Kentucky. Construction of protective water quality criteria for the protection of aquatic life from the chronic adverse effects of selenium that relies on measures in fish tissue over measures in associated water when both data are available reflects the increased accuracy and precision of fish tissue measurements in discerning thresholds for adverse effects and protective levels.

Literature Cited

Adam, M.D., M.J. Lacki, and T.G. Barnes. 1994. Foraging areas and habitat use of the Virginia big-eared bat in Kentucky. *The Journal of Wildlife Management* 58(3):462–469.

Ahlstedt, S. 1983. *Recovery Plan for the Dromedary Pearly Mussel (Dromus dromus) and Dromus dromas form caperatus* (Lea, 1834, 1845). U.S. Fish and Wildlife Service, Atlanta, GA.

Ahlstedt, S.A. 1984. Twentieth century changes in the freshwater mussel fauna of the Clinch River (Tennessee and Virginia). M.S. Thesis, The University of Tennessee, Knoxville, Tennessee. 102 pp.

Ahlstedt, S. A. 1986. Cumberland Mollusk Conservation Program. Activity 1: Mussel Distribution Surveys. Tennessee Valley Authority, Norris, TN. January 1986. 125 pp.

Ahlstedt, S.A. and J.J. Jenkinson. 1991. Distribution and abundance of *Potamilus capax* and other freshwater mussels in the St. Francis River system, Arkansas and Missouri, U.S.A. Walkerana, 5(14): 225-261.

Ahlstedt, S.A. and J.M. Tuberville. 1997. Quantitative reassessment of the freshwater mussel fauna in the Clinch and Powell rivers, Tennessee and Virginia. Pages 72-97 in K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, eds. Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Amyot. J. and J.A. Dowing, Endo- and epibenthic distribution of the unionid mollusk Elliptio complanta, by The North American Benthological Society 1991,10(3):280-285.

Amyot, J.-P. and J.A. Downing.1997. Seasonal variation in vertical and horizontal movement of the freshwater bivalve Elliptio complanata (Mollusca: Unionidae). *Freshwater Biology* 37: 345-354.

Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1):7-11.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. The University of Kentucky Press, Lexington, Kentucky.

Barr, W.C., S.A. Ahlstedt, G.D. Hickman, and D.M. Hill. 1993-1994. Cumberlandian mollusk conservation program. Activity 8: Analysis of macrofauna factors. Walkerana 7(17/18):159-224.

Barwick, D.H., and R.D. Harrell. 1997. Recovery of fish populations in Belews Lake following selenium contamination. Proceedings of the annual Conference of Southeastern Association of Fish and Wildlife Agencies 51:209-216.

Bates, J. M., and S. D. Dennis. 1985. Mussel Resource Survey - State of Tennessee. Tennessee Wildlife Resources Agency, Technical Report No. 85-4. 125 pp.

Belvins, D.W. 2011. *Water-Quality Requirements, Tolerances, and Preferences of Pallid Sturgeon (Scaphirhynchus albus) in the Lower Missouri River*. Scientific Investigations Report 2011-5186. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

Bennett, J.W. 2003. *Programmatic Biological Assessment for the Revised Land and Resource Management Plan Daniel Boone National Forest*. Prepared for U.S. Fish and Wildlife Service.

Best et al. 1997. Diet of Myotis Grisescens. Journal of Mammology. 78(2): 569-583.

Biggins, R.G. 1991. *Recovery Plan for Cracking Pearlymussel (*Hemistena lata*)*. U.S. Fish and Wildlife Service, Atlanta, GA.

Bock, L. R., R. R. Goforth, T. Stefanavage, and M. Sepulveda. 2011. Diet of shovelnose sturgeon in the Middle Wabash River, Indiana (USA). *Journal of Applied Ichthyology*. 27:309 315.

Boepple, J.F. and R.E. Coker. 1912. Mussel resources of the Holston and Clinch Rivers of eastern Tennessee. Bureau of Fisheries Document 765. 13pp.

Bogan, A.E. and P.W. Parmalee. 1983. Tennessee's rare wildlife. Vol. 2: The mollusks. Tennessee Wildlife Resources Agency and the Tennessee Conservation Department: Nashville, Tennessee. 123 pp.

Bouvier, L.D., A. Paquet, and T.J. Morris. 2013. *Information in Support of a Recovery Potential Assessment of Hickorynut (*Obovaria olivaria*) in Canada*. Research Document 2013/041. Canadian Science Advisory Secretariat (CSAS). Accessed December 2014. http://www.dfo mpo.gc.ca/Library/350232.pdf.

Braaten, P.J., D.B. Fuller, R.D. Lott, T.M. Haddix, L.D. Holte, R.H. Wilson, M.L. Bartron, J.A. Kalie, P.W. DeHaan, W.R. Ardren, R.J. Holm, and M.E. Jaeger. 2012. Natural growth and diet of known-age pallid sturgeon (*Scaphirhynchus albus*) early life stages in the upper Missouri River basin, Montana and North Dakota. *Journal of Applied Ichthyology* 28:496–504.
Brack, V., Jr., and R. K. LaVal. 1985. Food habits of the Indiana bat in Missouri. J. Mammalogy 66:308-315.

Brack, V. Jr. and R.K. LaVal. 2006. Diet of the gray myotis (*myotis grisescens*): Variability and consistency, opportunism, and selectivity. *Journal of Mammalogy* 87(1):7–18.

Brady, J., T. Kunz, M. D. Tuttle, and D. Wilson. 1982. Gray Bat Recovery Plan. U.S. Fish Wildlife Service 140 pp.

Brady, J., R. L. Clawson, R. K. LaVal, T. Kunz, M. D. Tuttle, and D. Wilson. 1983. Recovery plan for the Indiana bat. U. S. Fish Wildlife Service, Rockville, Maryland. 94 pp.

Branson, B. A., and G. A. Schuster. 1982. The fishes of the wild river section of the Little South Fork of the Cumberland River, Kentucky. Transactions of the Kentucky Academy of Science 43(1-2):60-70.

Brim Box, J. 1999. Community structure of freshwater mussels (Mollusca: Bivalvia) in coastal plain streams of the southeastern United States. Unpublished PhD. Dissertation, University of Florida, Gainesville, Florida. 107 pp.

Brim Box and Mosa 1999 Sediment, land use, and freshwater mussels: Prospects and problems, Journal of the North American Benthological Society

Buchanan, A.C. 1980. Mussels (naiades) of the Merrimac River Basin. Missouri Department of Conservation, Aquatic Series, 17: 1-68.

Buchanan, A.C. 1994. A survey of the freshwater mussels of the lower Gasconade River. Report for U.S. Army of Corps of Engineers, Kansas City District, 700 Federal Building, Kansas City, MO 64106.

Burford, L. S., and M. J. Lacki. 1995. Habitat use by Corynorhinus townsendii virginianus in the Daniel Boone National Forest. American Midland Naturalist 134:340-345.

Burford, L.S., and M.J. Lacki. 1998. Moths consumed by *corynorhinus townsendii virginianus* in Eastern Kentucky. *American Midland Naturalist* 139(1):141–146.

Burger, J. 1993. Shorebird squeeze. Natural History 5/93, pp. 8-14.

Burr, B. M., and M. L. Warren, Jr. 1986. Distributional atlas of Kentucky fishes. Kentucky Nature Preserves Commission, Scientific and Technical Series No. 4, Frankfort, Kentucky. 398 pp.

Burr, B. M., and M. L. Warren, Jr. 1986. Threatened fishes of the world: *Etheostoma chienense* Page & Ceas, 1992 (Percidae). Environmental Biology of Fishes 47:142.

Butler, R.S., R.R. Cicerello, and E.L. Laudermilk. 1997. *Obovaria retusa*: confirmation of an extant population in the upper Green River, Kentucky. Triannual Unionid Report, 13: 16.

Butler, R.S., and R.G. Biggins. 2004. *Recovery Plan for Cumberland Elktoe (*Alasmidonta atropurpurea*), Oyster Mussel (*Epioblasma capsaeformis*), Cumberlandian Combshell (*Epioblasma brevidens*), Purple Bean (*Villosa perpurpurea*), and Rough Rabbitsfoot (*Quadrula cylindrica strigillata*)*. U.S. Fish and Wildlife Service, Atlanta, GA.

Caceres, M. C., and R. M. R. Barclay. 2000. MYOTIS SEPTENTRIONALIS. Mammalian Species No. 634:1-4.

Caire, W., J. D. Tyler, B. P. Glass, and M. A. Mares. 1989. Mammals of Oklahoma. University of Oklahoma Press, Norman. Oklahoma. 567 pp.

Campbell, C.I. 2011. Rationale for the EPA's Action on the Revisions to Utah Water Quality Standards. U.S. Environmental Protection Agency, Region 8. Denver, CO.

Canadian Wildlife Service and U.S. Fish and Wildlife Service (CWS and USFWS). 2007. International recovery plan for the whooping crane. Ottawa: Recovery of Nationally Endangered Wildlife (RENEW), and U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 162 pp.

Canton, S. 2010. Persistence of Some Fish Populations in High-Se Environments. Appendix B in: Chapman P.M., W.J. Adams, M.L. Brooks, C.G. Delos, S.N. Luoma, W.A. Maher, H.M. Ohlendorf, T.S. Presser, D.P. Shaw (eds). Ecological Assessment of Selenium in the Aquatic Environment. SETAC Press, Pensacola, FL, USA.

Carter, T.C., M.A. Menzel, S.F. Owen, J.W. Edwards, J.M. Menzel, and W.M. Ford. 2003. Food habits of seven species of bats in the Allegheny Plateau and Ridge and Valley of West Virginia. *Northeastern Naturalist* 10(1):83–88.

Carter, T.C. 2006. Indiana bats in the Midwest: The importance of hydric habitats. *The Journal of Wildlife Management* 70(5):1185–1190.

Center for Biological Diversity. 2010. Petition to list the eastern small-footed bat Myotis leibii and northern long-eared bat Myotis septentrionalis as threatened or endangered under the Endangered Species Act. Center for Biological Diversity, P.O. Box 188, Richmond, VT

Chapman PM, Adams WJ, Brooks ML, Delos CG, Luoma SN, Maher WA, Ohlendorf HM, Presser TS, Shaw DP. 2009. Ecological assessment of selenium in the aquatic environment: Summary of a SETAC Pellston Workshop. Pensacola FL (USA): Society of Environmental Toxicology and Chemistry (SETAC).

Chapman P.M., W.J. Adams, M.L. Brooks, C.G. Delos, S.N. Luoma, W.A Maher, H.M. Ohlendorf, T.S. Presser and D.P. Shaw (eds). 2010. Ecological Assessment of Selenium in the Aquatic Environment. SETAC Press, Pensacola, FL, USA.

Christian, A.D., Smith, B.N., Berg, D.J., Smoot, J.C., and Findlay, R.H. 2004. Trophic position and potential food sources of 2 species of unionid bivalves (Mollusca: Unionidae) in 2 small Ohio streams. Journal of the North American Benthological Society 23:101-113.

Cicerello, R.R. and G.A. Schuster. 2003. A guide to the freshwater mussels of Kentucky. Kentucky State Nature Preserves Commission Scientific and Technical Series 7:1-62.

Clare, E.L, B.R. Barber, B.W. Sweeney, P.D.N. Hebert, and M.B. Fenton. 2011. Eating local: influences of habitat on the diet of little brown bats (*myotis lucifugus*). *Molecular Ecology* 20:1772–1780.

Clarke, A.H. 1981. The freshwater mollusks of Canada. National Museum of Natural Sciences, National Museums of Canada, D. W. Friesen and Sons, Ltd.: Ottawa, Canada. 446 pp.

Clark, D. R., R. K. LaVal, and A. J. Krynitsky. 1980. Dieldrin and heptachlor residue in dead gray bats, Franklin County, Missouri, USA: 1976 vs 1977. Pesticide Monitoring Journal 13:137-40.

Clark, D. R., R. K. LaVal, and D. M. Swineford. 1978. Dieldren-induced mortality in an endangered species, the gray bat (MYOTIS GRISESCENS). Science 199:1357-9.

Clark, D. R., R. K. LaVal, and M. D. Tuttle. 1982. Estimating pesticide burdens of bats from guano analyses. Bull. Environ. Contam. Toxicol. 29:214-20.

Clarke, A.H. 1983. The distribution and relative abundance of *Lithasia pinguis* (Lea), *Pleurobema plenum* (Lea), *Villosa trabalis* (Conrad), and *Epioblasma sampsoni* (Lea). American Malacological Bulletin, 1: 27-30.

Cochran, T.G. II and J.B. Layzer. 1993. Effects of commercial harvest on unionid habitat use in the Green and Barren Rivers, Kentucky. Pages 61-65 in K.S. Cummings, A.C. Buchanan, and L.M. Koch (eds.) Conservation and Management of Freshwater Mussels: Proceedings of a UMRCC Symposium, 12-14 October, 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 189 pp.

Coker, R.E., A.F. Shira, H.W. Clark, and A.D. Howard. 1921. Natural history and propagation of fresh-water mussels. Bulletin of the Bureau of Fisheries [Issued separately as U.S. Bureau of Fisheries Document 839] 37(1919-20):77-181 + 17 pls.

Cope, W.G., R.B. Bringolf, D.B. Buchwalter, T.J. Newton, C.G. Ingersoll, N. Wang, T. Augspurger, F.J. Dwyer, M.C. Barnhart, R.J. Neves, and E. Hammer. 2008. Differential exposure, duration, and sensitivity of unionoidean bivalve life stages to environmental contaminants. *Journal of the North American Benthological Society* 27(2):451–462.

Crane et al, *The toxicity of selenium in experimental freshwater ponds*, Archives of Environmental Contaminant Toxicology, Nov. 1992, Vol 23(4), pp440-52

Cummings, K. S., C. A. Mayer, L. M. Page, and J. M. Berlocher. 1987. Survey of the Freshwater Mussels (Mollusca: Unionidae) of the Wabash River Drainage, Phase I: Lower Wabash and Tippecanoe Rivers. Technical Report 1987(5), Illinois State Natural History Survey Division. 60 pp., plus Appendices I, II, and III.

Crutchfield, Jr., J.U. 2000. Recovery of a power plant cooling reservoir ecosystem from selenium bioaccumulation. Environmental Science and Policy 3:S145-S163.

Cummings, K. S., C. A. Mayer, and 1. M. Page. 1988. Survey of the Freshwater Mussels (Mollusca: Unionidae) of the Wabash River Drainage, Phase II: Upper and Middle Wabash River. Technical Report. 1988(8), Illinois State Natural History Survey Division. 47 pp., plus Appendix I.

Cummings, K.S., M.E. Retzer, C.A. Mayer, and L.M. Page. 1990. Life history aspects and status of the federally endangered fatpocket, *Potamilus capax* (Green, 1832) (Mollusca: Unionidae) in the Lower Wabash River, Illinois and Indiana. Illinois Natural History Survey, Center for Biodiversity, Technical Report, 1990(1): 1-37.

Cummings, K.S. and C.A. Mayer. 1992. Field Guide to Freshwater Mussels of the Midwest. Illinois Natural History Survey Manual 5, Illinois. 194 pp.

Cummings, K.S. and C.A. Mayer. 1993. Distribution and host species of the federally endangered freshwater mussel, *Potamilus capax* (Green, 1832) in the Lower Wabash River, Illinois and Indiana. Illinois Natural History Survey, Center for Biodiversity, Technical Report, 1993(1): 1-29.

Cummings, K., and J. Cordeiro. 2012. *Cumberlandia monodonta*. The IUCN Red List of Threatened Species. Version 2014.3. International Union for Conservation of Nature. Accessed January 2015. http://www.iucnredlist.org/details/5952/0.

Davis, V.M., and J.B. Layzer. 2012. Life history of the fluted kidneyshell *Ptychobranchus subtentum*. *American Midland Naturalist* 167(1):79–95.

Decher, J., and J. R. Choate. 1995. MYOTIS GRISESCENS. Mammalian Species (510):1-7.

De Grave, S., and C. Rogers. 2013. *Palaemonias ganteri*. The IUCN Red List of Threatened Species. Version 2014.3. International Union for Conservation of Nature. Accessed December 2014. http://www.iucnredlist.org/details/15888/0.

Dennis, S.D. 1984. Distributional analysis of the freshwater mussel fauna of the Tennessee River system, with special reference to possible limiting effects of siltation. Ph.D. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 247 pp.

Diplock, P. M. and W. G. Hoekstra. 1976. Metabolic aspects of selenium action and toxicity. Crit. Rev. Toxicol. 5:271-329.

Dodd, L.E., E.G. Chapman, J.D. Harwood, M.J. Lacki, and L.K. Reeske. 2012. Identification of prey of *myotis septentrionalis* using DNA-based techniques. *Journal of Mammalogy* 93(4):1119 1128.

Dryer and Sandvol 1993. Recovery plan for the pallid sturgeon. Denver, CO: U.S. FWS.

Egerer-Sieber C, Herl V, Muller-Uri F, Kreisb W, Muller YA. 2006. Crystallization and preliminary crystallographic analysis of selenomethionine-labelled progesterone 5*b*-reductase from *Digitalis lanata* Ehrh. *Acta Crystall Sec F* 62:186–188.Eisenhour, D. J., and R. M. Strange. 1998. Threatened fishes of the world: *Phoxinus cumberlandensis* Starnes & Starnes, 1978 (Cyprinidae). Environmental Biology of Fishes 51:140.

Ellis, M. M., Erosion Silt as a Factor in Aquatic Environments, *Ecology* Vol. 17, No. 1 (Jan., 1936), pp. 29-42 Published by: Ecological Society of America

Endangered Species Information System. 1996. October 1 – last update. Fish and Wildlife Information Exchange-VA Tech. Online. Available: http://www.fw.vt.edu/fishex/esis.html

Etnier, D.A. and Starnes, W.C., 1993. The fishes of Tennessee. University of Tennessee Press, Knoxville, Tennessee. 681 pp.

Evermann, B.W. and H.W. Clark. 1918. The Unionidae of Lake Maxinkukee. Proceedings of the Indiana Academy of Science 1917:251-285.

Federal Register / Vol. 58, No. 13 / Friday, January 22, 1993 / Rules and Regulations DEPARTMENT OFTHE INTERIOR Fish and Wildlife Service 50 CFR Part 17 RIN 1O18—A875 I Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Northern Riffleshell mussel (Epioblasma torulosa rangiana) and the Clubshell mussel (Pleurobema clava)

Federal Register Volume 62, Number 7 (Friday, January 10, 1997) [pages 1647 – 1659] Department of the Interior Fish and Wildlife Service 50 CFR Part 17 Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot

Federal Register Volume 66, Number 115 (Thursday, June 14, 2001) [Rules and Regulations] [Pages 32250-32264] DEPARTMENT OF THE INTERIOR Fish and Wildlife Service 50 CFR Part 17 RIN 1018-AE92 Endangered and Threatened Wildlife and Plants; Establishment of Nonessential Experimental Population Status for 16 Freshwater Mussels and 1 Freshwater Snail (Anthony's Riversnail) in the Free-Flowing Reach of the Tennessee River below the Wilson Dam, Colbert and Lauderdale Counties, AL

Federal Register Volume 78, Number 144 (Friday, July 26, 2013 [Rules and Regulations] [Pages 45074-45095] DEPARTMENT OF THE INTERIOR Fish and Wildlife Service 50 CFR Part 17 [Docket No. FWS-R5-ES-2012-0045; 4500030113] RIN 1018-AY12 Endangered and Threatened Wildlife and Plants; Endangered Species Status for Diamond Darter

Federal Register / Vol. 78, No. 163 / Thursday, August 22, 2013 / Rules and Regulations Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Diamond Darter

Federal Register. DEPARTMENT OF THE INTERIOR, Fish and Wildlife Service, 50 CFR Part 17, [Docket No. FWS–R5–ES–2013–0097; 4500030114] RIN 1018–AY17 Endangered and Threatened Wildlife and Plants; Proposed Threatened Status for the Rufa Red Knot (Calidris canutus rufa) AGENCY: Fish and Wildlife Service, Interior. 27548 Federal Register / Vol. 79, No. 93 / Wednesday, May 14, 2014 / Proposed Rules

Federal Register Online via the Government Printing Office [www.gpo.gov]
[FR Doc No: 2013-17938] Diamond darter

Fenton, M. B. 1982. Echolocation, insect hearing, and feeding ecology of insectivorous bats. Pages 261-85 in T. H. Kunz (editor). Ecology of Bats. Plenum Press, New York, New York.

Fisher, B.E. 2006. Current status of freshwater mussels (Order Unionoida) in the Wabash River drainage of Indiana. Proceedings of the Indiana Academy of Science, 115(2): 103-109.

Fraley S.J. and Ahlstedt S.A. 2000. The recent decline of the native mussels (Unionidae) of Copper Creek, Russell and Scott Counties, Virginia. In: Tankersley R.A., Warmolts D.I., Watters G.T., Armitage B.J., Johnson P.D. and Butler R.S. (eds) Freshwater Mollusk Symposia Proceedings. Ohio Biological Survey, Columbus, Ohio, pp. 189–195.

Fremling, C. R. 1968. Documentation of a mass emergence of Hexagenia mayflies from the Upper Mississippi River. Trans. Amer. Fish Soc. 97:278-80.

Gargas, A., M. T. Trest, M. Christensen, T. J. Volk, and D. Blehert. 2009. *Geomyces destructans* sp. nov. associated with bat white-nose syndrome. Mycotaxon 108: 147 – 154.

GEI Consultants, Inc., Golder Associates, Parametrix, and University of Saskatchewan Toxicology Centre. 2008. Selenium tissue thresholds: tissue selection criteria, threshold development endpoints, and field application of tissue thresholds. Report to: North American Metals Council-Selenium Working Group, Washington, DC.

Gerrity, P.C., C.S. Guy, and W.M. Gardner. 2006. Juvenile pallid sturgeon are piscivorous: A call for conserving native cyprinids. *Transactions of the American Fisheries Society* 135(3):604 609.

Gordon, M.E. and J.B. Layzer. 1989. Mussels (Bivalvia: Unionoidea) of the Cumberland River review of life histories and ecological relationships. U.S. Fish and Wildlife Service Biological Report, 89(15): 1-99.

Goodrich, C. and H. van der Schalie. 1944. A revision of the mollusca of Indiana. Am. Midi. Nat.32(2):257-326.

González, P. M., A. J. Baker, and M. E. Echave. 2006. Annual survival of red knots (*Calidris canutus rufa*) using the San Antonio Oeste stopover site is reduced by domino effects involving late arrival and food depletion in Delaware Bay. Hornero 21(2):109-117.

Grabarkiewicz, J.F., and W.S. Davis. 2008. *An Introduction to Freshwater Mussels as Biological Indicators—Including Accounts of Interior Basin, Cumberlandian, and Atlantic Slope Species*. EPA-260-R-08-015. U.S. Environmental Protection Agency. Accessed January 2015. http://nepis.epa.gov/Adobe/PDF/P1002IYI.PDF.

Griffith, L. A., and J. E. Gates. 1985. Food habits of cave-dwelling bats in the central Appalachians, Journal of Mammalogy 66(3):451-60.

Grohs, K.L., R.A. Klumb, S.R. Chipps, and G.A. Wanner. 2009. Ontogenetic patterns in prey use by pallid sturgeon in the Missouri River, South Dakota and Nebraska. *Journal of Applied Ichthyology*. 25(2):48–53.

Hall, E. R. 1981. The Mammals of North America, 2nd. Ed., 2 Vols. John Wiley and Sons, New York 1181 pp.

Hall, J. S. 1962. A life history and taxonomic study of the Indiana bat, *Myotis sodalis*. Reading Publication Museum Art Gallery, Science Publication 12. 68 pp.

Hamilton et.al. 2000. Chronic Toxicity and Hazard Assessment of an Inorganic Mixture Simulating Irrigation Drainwater to Razorback Sucker and Bonytail. Environ Toxicol 15: 48-64.

Hamilton, W. J., Jr., and J. O. Whitaker, Jr. 1979. Mammals of the eastern United States. Cornell Univ. Press, Ithaca, New York. 346 pp.

Harker, D. F., Jr., S. M. Call, M. L. Warren, Jr., K. E. Camburn, and P. Wigley. 1979. Aquatic biota and water quality of the Appalachian Province, eastern Kentucky. Kentucky Nature Preserves Commission Technical Report, Frankfort, Kentucky.

Harker, D. F., Jr., M. L. Warren, Jr., K. E. Camburn, S. M. Call, G. J. Fallo, and P. Wigley. 1980. Aquatic biota and water quality of the upper Cumberland River basin. Kentucky Nature Preserves Commission Technical Report, Frankfort, Kentucky.

Harrington, Brian A. 2001. Red Knot. The Birds of North America. Vol. 15, No. 563: American Orinithologists' Union. The Academy of Natural Sciences of Philadelphia.

Harris, J.L. and M.E. Gordon. 1987. Distribution and status of rare and endangered mussels (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Proceedings of the Arkansas Academy of Science, 41: 49-56.

Harris, J.L., P.J. Rust, A.C. Christian, W.R. Posey II, C.L. Davidson, and G.L. Harp. 1997. Revised status of rare and endangered Unionacea (Mollusca: Margaritiferidae, Unionidae) in Arkansas. Journal of the Arkansas Academy of Science, 51: 66-89.

Harrison, A.B., W.T. Slack, and K.J. Killgore. 2014. Feeding habitats of young-of-year river sturgeon *Scaphirhynchus spp*. in the Lower Mississippi River. *The American Midland Naturalists* 171:54–67.

Hartfield, H. 1993. Headcuts and their effect on freshwater mussels. Pages 131-141 in K.S. Cummings, A.C. Buchanan, and L.M. Koch. (eds.). Conservation and Management of Freshwater Mussels. Proceedings of a UMRCC Symposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 189 pp.

Hartfield, P.D., and E. Hartfield. 1996. Observations on the conglutinates of *Ptychobranchus greeni* (Conrad, 1834) (Mollusca: Bivalvia: Unionoidea). American Midland Naturalist 135:370-375.

Harvey, M. J. 1992. Bats of the eastern United Sates, Arkansas Game and Fish Commission in cooperation with the U. S. fish and Wildlife Service and Tennessee Technological University, Little Rock, AR.

Harvey, M. J., J. R. MacGregor, and R. R. Currie. 1991. Distribution and status of Chiroptera in Kentucky and Tennessee. J. of Tenn. Acad. of Sci. 66(4):191-193.

Haygarth, P. M. 1994. Global Importance and Global Cylcling of Selenium. In: Selenium in the Environment. Eds. Frankenberger, W.T. and S Benson. Marcel Dekker, Inc. New York.

Heard, W.H. 1970. Eastern freshwater mollusks. 1. The south Atlantic and Gulf drainages. In: A.H. Clarke (ed.) Rare and endangered molluscs of North America. Malacologia 10:1-56.

Herkert, J. R., editor. 1992. Endangered and threatened species of Illinois: status and distribution. Vol. 2: Animals. Illinois Endangered Species Protection Board. iv + 142 pp.

Hickman, M.E. 1937. A contribution to the Mollusca of eastern Tennessee. MS Thesis, University of Tennessee, Knoxville, Tennessee. 165 pp.

Hoffman DJ. 2002. Role of selenium toxicity and oxidative stress in aquatic birds. *Aquat Toxicol* 57:11-26.

Hoggarth, M.A., D.L. Rice, and D.M. Lee. 1995. Discovery of the federally endangered freshwater mussel, *Epioblasma obliquata obliquata* (Rafinesque, 1820) (Unionidae), in Ohio. Ohio Journal of Science 95(4):298-299.

Hoover, J.J., S.G. George, and K.J. Killgore. 2007. Diet of shovelnose sturgeon and pallid sturgeon in the free-flowing Mississippi River. *Journal of Applied Ichthyology* 23:494–499.

Horne, F.R. and S. McIntosh. 1979. Factors influencing distribution of mussels in the Blanco River of central Texas. The Nautilus 94(4):119-133.

Hove, M.C., J.R. Medland, D.J. Hornbach, M.P. Cliff, M.G. Haas, A.R. Kapuscinski, R.K. Whaley, B.N. Karns, D.C. Allen, R.S. Derhak, K.M. Swensen, and J.E. Thomas. 2002. Federally endangered winged mapleleaf mussels cultured and placed in the St. Croix River, Minnesota. Engangered Species Update, 19(1): 3-4.

Hove, M., M. Berg, K. Dietrich, C. Gonzales, D. Hornbach, K. Juleen, M. Ledford, M. Marzec, M. McGill, C. Nelson, B.J. Ritger, J. Selander, and A. Kapuscinski. 2003. High school students participate in snuffbox host suitability trials. Ellipsaria, 5(3): 19-20.

Hove, M., M. Berg, J. DeMarre, K. Dietrich, C. Gonzales, K. Westberg, and D. Hornbach. 2003. Historical range expansion of winged mapleleaf provides possibilities for additional reintroduction sites. Ellipsaria, 5(3): 17-18.

Hrabik, R.A., D.P. Herzog, D.E. Ostendorf, and M.D. Petersen. 2007. Larvae provide first evidence of successful reproduction by pallid sturgeon, *scaphirhynchus albus*, in the Mississippi River. *Journal of Applied Ichthyology* 23:436–443.

Hubbard, W.D., D.C. Jackson, and D.J. Ebert. 1993. Channelization. Pages 135-155 in E.F. Bryan and D.A. Rutherford (eds.) Impacts on warm-water streams: guidelines for evaluation. Warm-water Stream Committee, Southern Division, American Fisheries Society, Little Rock, Arkansas.

Humphrey, S. R., A. R. Richter, and J. B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, (Myotis sodalis). J. Mammalogy 58:334-346.

Hunt, H. E., and R. D. Slack. 1989. Winter diets of whooping and sandhill cranes in south Texas. J. Wildlife Management 53:1150-1154.

Isom, B.G., C. Gooch, and S.D. Dennis. 1979. Rediscovery of a presumed extinct river mussel, *Dysnomia sulcata* (Unionidae). The Nautilus, 93(2-3): 84.

Jackson, H. H. 1961. Mammals of Wisconsin. University of Wisconsin Press, Madison. 504 pp.

Janz D, Behnke K, Schnitzler J-P, Kanawati B, Schmitt-Kopplin P, Polle A. (2010) Pathway analysis of the transcriptome and metabolome of salt sensitive and tolerant poplar species reveals evolutionary adaption of stress tolerance mechanisms. BMC Plant Biol 10: 150

Jelks, H.L., S.J. Walsh, N. M. Burkhead. S. Contreras-Balderas, E. Diaz-Pardo, D. A. Hendrickson, J. Lyons, N. E. Mandrak, F. McCormick, J. S. Nelson, S. P. Platania, B. A. Porter, C. B. Renaud, J. Jacobo Schmitter-Soto, E. B. Taylor, and M. L. Warren, Jr. 2008. Conservation status of imperiled North American Freshwater and diadromous fishes. Fisheries 33(8):372-407.

Jenkinson, J.J. and S.A. Ahlsedt. 1988. Quantitative reassessment of the freshwater mussel fauna in the Clinch River, Tennessee and Virginia. Tennessee Valley Authority, Knoxville, Tennessee. 28 pp.

Jenkinson, J.J. and S.A. Ahlstedt. 1995. A search for additional populations of *Potamilus capax* in the St. Francis and Cache river watersheds, Arkansas and Missouri, U.S.A. Walkerana, 7(17/18): 71-157.

Johnson, R.I. 1978. Systematics and zoogeography of *Plagiola* (= *Dysnomia* = *Epioblasma*), an almost extinct genus of freshwater mussels (Bivalvia: Unionidae) from middle North America. Bulletin of the Museum of Comparative Zoology, 148(6): 239-320.

Johnson, R. I..1980. Zoogeography of North American Unionacea.(Mollusca: Bivalvia) North of the Maximum Pleistocene Glaciation. Bulletin of the Museum of Comparative Zoology. 149(2): 77-189.

Johnson, P.D., C. St. Aubin, and S.A. Ahlstedt. 2005. Freshwater mussel survey results for the Cherokee and Chattahoochee districts of the United States Forest Service in Tennessee and Georgia. Report to the U.S. Fish and Wildlife Service, Daphne, Alabama. 32 pp.

Johnson, J.B., J.H. Roberts, T.L. King, J.W. Edwards, W.M. Ford, and D.A. Ray. 2014. Genetic structuring of the northern myotis (*myotis septentrionalis*) at multiple spatial scales. *Acta Theriologica* 59:223–231.

Jones, J.W. and R.J. Neves. 2000. Life history aspects of the endangered fanshell pearly mussel (Cyprogenia stegaria) (Bivalvia:Unionidae), draft manuscript submitted to Journal of the North American Benthological Society, Nov. 2000. In: Life History and Artificial Culture of Endangered Mussels. Annual Progress Report for 2000. Virginia Cooperative Fish and Wildlife Research Unit, Blacksburg, VA. pp. 20-72.

Jones, J.W., and R.J. Neves. 2002. Life history and propagation of the endangered Fanshell pearlymussel, *Cyprogenia stegaria Rafinesque* (Bivalvia:Unionidae). *Journal of the North American Benthological Society* 21(1):76–88.

Jones, J.W., R.J. Neves, S.A. Ahlstedt, and R.A. Mair. 2004. Life history and propagation of the endangered dromedary pearlymussel (*Dromus dromas*) (Bivalvia: Unionidae). Journal of the North American Benthological Society, 23(3): 515-525.

Koch, B., R.C. Brooks, A. Oliver, D. Herzog , J.E. Garvey, R. Hrabik , R. Colombo, Q. Phelps, and T. Spier. 2012. Habitat selection and movement of naturally occurring pallid sturgeon in the Mississippi River. *Transactions of the American Fisheries Society* 141(1):112–120.

Kuhajda, B.R., A.L. George, and J.D. Williams. 2009. The desperate dozen: Southeastern freshwater fishes on the brink. *Southeastern Fishes Council Proceedings* 51:10–31.

Kunz, T. H. 1971. Reproduction of some vespertilionid bats of central Iowa. Amer. Midl. Nat. 86(2):477-86.

Kunz, T. H. 1973. Resource utilization: Temporal and spatial components of bat activity in central Iowa. Journal of Mammalogy 54(1):14-32

Kurta, A. 1982. A review of Michigan Bats: Seasonal and geographic distribution. Mich. Acad. 14(3):295-312.

Kurta, A. and J.O. Whitaker Jr. 1998. Diet of the endangered Indiana bat (Myotis sodalis) on the northern edge of its range. American midland Naturalist 140(2):280-286.

Lacki, M.J., D.R. Cox, L.E. Dodd, and M.B. Dickinson. 2009. Response of northern bats (*myotis septentrionalis*) to prescribed fires in eastern Kentucky forests. *Journal of Mammalogy* 90(5):1165–1175.

Langwig, K., A. Hicks, R. von Linden, C. Herzog, S. Darling, T. French, and J. Armstrong. 2009. White nose syndrome related declines of hibernating bat species in the Northeast. Presentation at 2009 North American Society for Bat Research symposium, Portland, Oregon.

Laudermilk, E. L., and R. R. Cicerello, Compilers. 1998. Upper Cumberland River Drainage, Kentucky Fish Collection Catalog (1982-1994). Kentucky State Nature Preserves Commission. 469 pp.

LaVal, R. K., R. L. Clawson, M. L. LaVal and W. Caire. 1977. Foraging Behavior and Nocturnal Activity Patterns of Missouri Bats, with Emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. Journal of Mammalogy 58(4):592-599

LaVal, R. K., and M. L. LaVal. 1980. Ecological studies and management of Missouri bats, with emphasis on cave dwelling species. Terrestrial Series 8, Missouri Department of Conservation.

Layne, J. N., editor. 1978. Rare and endangered biota of Florida. Vol. 1. Mammals. State of Florida Game and Freshwater Fish Commission. xx + 52 pp.

Layman, S.R. 1991. Life history of the relict, duskytail darter, *Etheostoma (Catonotus) sp*., in Little River, Tennessee. *American Society of Ichthyologists and Herpetologists* 1991(2):471-485.

Layzer, J.B, and M.E. Gordon. 1990. Development and testing of sampling designs for assessing mussel populations in medium and large size rivers: final report. Tennessee Wildlife Resources Agency, Nashville, Tennessee. 25 pp.

Layzer J.B., Gordon M.E., Anderson R.M. *(*1993*)* Mussels: the forgotten fauna of regulated rivers: a case study of the Caney Fork River. *Regulated Rivers: Research and Management,* 8**,** 63–71.

Lee, Y.F., and G.F. McCracken. 2004. Flight activity and food habits of three species of Myotis bats (chiroptera: vespertilionidae) in sympatry. *Zoological Studies* 43(3):589–597.

Leftwich, K. N., M. K. Underwood, and C. A. Dolloff. 1995. Distribution and abundance of blackside dace *Phoxinus cumberlandensis* in Middle Fork Beaver Creek. Center for Aquatic Technology Transfer, Department of Fisheries and Wildlife Science, Virginia Tech, Blacksburg, Virginia. 6+ pp.

Leitheuser, A. 1988. Kentucky Cave Shrimp Recovery Plan. U.S. Fish and Wildlife Service, Atlanta Georgia.

Lemly AD. 1993b. Guidelines for evaluating selenium data from aquatic monitoring and assessment studies. *Environ Mon Assess* 28:83-100.

Lemly AD. 1997b. Ecosystem recovery following Se contamination in a freshwater reservoir. *Ecotoxicol Environ Saf* 36:275-281.

Lemly, A. D. 2002. Symptoms and implications of selenium toxicity in fish: the Belews Lake case example. Aqua. Toxicol. 57:39-49.

Lisowski 1983. Distribution, Habitat, and Behavior of the Kentucky Cave Shrimp Palaemonias ganteri Hay. Journal of Crustacean Biology. Vol. 3, No. 1 : 88-92.

Lott, C.A. 2006. Distribution and abundance of the interior population of the least tern (Sternula antillarum), 2005: a review of the first complete range-wide survey in the context of historic and ongoing monitoring efforts. Dredging Operations and Environmental Research Program, U.S. Army Corps of Engineers, Engineer Research and Development Center,

ERDC/EL TR-06-13.Luckey, T.D, and Venugopal, B. 1977. Metal Toxicity in Mammals. Vol 1. New York, Plenum Press.

Luoma, S.N. and T.S. Presser. 2009. Emerging opportunities in management of selenium contamination: Environmental Science and Technology. 43:.8483-8487.
Maier KJ, Knight AW. 1994. Ecotoxicology of selenium in freshwater systems. *Rev Environ Contam Toxicol* 134:31-48.

Marking, L. L., T. D. Bills. 1979. Acute effects of silt and sand sedimentation on freshwater mussels. *UMRCC Symposium on Upper Mississippi River Bivalve Mollusks*. 204-211.

Matthews, J.R. and C.J. Moseley (eds.). 1990. The Official World Wildlife Fund Guide to Endangered Species of North America. Volume 1. Plants, Mammals. xxiii + pp 1-560 + 33 pp. appendix + 6 pp. glossary + 16 pp. index. Volume 2. Birds, Reptiles, Amphibians, Fishes, Mussels, Crustaceans, Snails, Insects, and Arachnids. xiii + pp. 561-1180. Beacham Publications, Inc., Washington, D.C.

McMahon, R.F., and A.E. Bogan. 2001. Mollusca: Bivalvia. In *Ecology and Classification of North American Freshwater Invertebrates*, 2^{nd} Edition, ed. Thorp, J.H., and A.P. Covich. Academic Press, New York.

Mechaly A, Teplitsky A, Belakhov V, Baasov T, Shoham G, Shoham Y. 2000. Overproduction and characterization of seleno-methionine xylanase T-6. *J Biotech* 78:83-86.

Meek, S. E., and H.W. Clark. 1912. The mussels of the Big Buffalo Fork of White River, Arkansas. Report and Special Papers of the U.S. Fish Commission [Issued separately as U.S. Bureau of Fisheries Document 759] 1911:1-20.

Metcalfe-Smith, J.L., G.L. Mackie, S.K. Staton, and E.L. West. 1998. Current status of rare species of freshwater mussels in southern Ontario. Triannual Unionid Report, 14: unpaginated.

Miller, A.C., B.S. Payne, and T. Siemsen. 1986. Description of the habitat of the endangered mussel *Plethobasus cooperianus*. *Nautilus* 100(1):14–18.

Miller, A.C. and B.S. Payne. 2005. The curious case of the fat pocketbook mussel, *Potamilus capax*. Endangered Species Update, 22(2): 61-70.

Mirarchi, R.E., J.T. Garner, M.F. Mettee, and P.E. O'Neil. 2004. Alabama wildlife. Volume 2. Imperiled aquatic mollusks and fishes. University of Alabama Press, Tuscaloosa, Alabama. xii + 255 pp.

Mohr, C. E. 1972. The status of threatened species of cave-dwelling bats. Bull. Nat. Speleol. Soc. 34(2):33-47

Morrison, R. I. G., R. K. Ross, and L. J. Niles. 2004. Declines in wintering populations of red knots in southern South America. Condor 106:60-70.

Mumford, R.E. and J.B. Cope. 1964. Distribution and status of the Chiroptera of Indiana. American Midland Naturalist 72(2):473-489.

Murray, H.D. & A.B. Leonard. 1962. Handbook of Unionid Mussels in Kansas. : 184 pp.

Musick, J. A. 1999. Ecology and conservation of long-lived marine animals. American Fisheries Society Symposium, 1999. 23:1-10.

Nagorsen, D. W. and R. M. Brigham. 1993. Bats of British Columbia. Vol. I. The Mammals of British Columbia. UBC Press, Vancouver, 164 pp.

NAMC, 2008. Selenium Tissue Thresholds: Tissue Selection Criteria, Threshold Development Endpoints, and Potential to Predict Population or Community Effects in the Field. Part III: Field Application of Tissue Thresholds: Potential to Predict Population or Community Effects in the Field. North America Metals Council – Selenium Working Group (NAMC).

NatureServe 2013. *Crystallaria cincotta*. The IUCN Red List of Threatened Species. Version 2014.2. <www.iucnredlist.org>. (Accessed: October 21, 2014).

NatureServe. 2014. *Leptodea leptodon.* NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Updated March 2014. (Accessed: January, 2015).
http://explorer.natureserve.org/servlet/NatureServe?searchName=Leptodea+leptodon

NatureServe. 2014. *Pleuronaia dolabelloides.* NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Updated March 2014. (Accessed: January, 2015). http://explorer.natureserve.org/servlet/NatureServe?sourceTemplate=tabular_report.wmt&loadTemplate=species_RptComprehensive.wmt&selectedReport=RptComprehensive.wmt&summaryView=tabular_report.wmt&elKey=106952&paging=home&save=true&startIndex=1&nextStartIndex=1&reset=false&offPageSelectedElKey=106952&offPageSelectedElType=species&offPageYesNo=true&post_processes=&radiobutton=radiobutton&selectedIndexes=106952

NatureServe. 2014. *Ptychobranchus subtentum* NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. (Accessed: January, 2015). http://explorer.natureserve.org/servlet/NatureServe?sourceTemplate=tabular_report.wmt&loadTemplate=species_RptComprehensive.wmt&selectedReport=RptComprehensive.wmt&summaryView=tabular_report.wmt&elKey=118056&paging=home&save=true&startIndex=1&nextStartIndex=1&reset=false&offPageSelectedElKey=118056&offPageSelectedElType=species&offPageYesNo=true&post_processes=&radiobutton=radiobutton&selectedIndexes=118056

NatureServe. 2014. *Plethobasus cyphyus.* NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. (Accessed: January, 2015). http://explorer.natureserve.org/servlet/NatureServe?searchName=Plethobasus+cyphyus+

NatureServe. 2014. *Pleurobema clava.* NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. (Accessed: January, 2015). http://explorer.natureserve.org/servlet/NatureServe?searchName=Pleurobema+clava+

NatureServe. 2014. *Plethobasus cicatricosus.* NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Updated March 1014 (Accessed: January, 2015). http://explorer.natureserve.org/servlet/NatureServe?searchName=Plethobasus+cicatricosus

NatureServe. 2014a. *Corynorhinus townsendii virginianus*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Corynorhinus+townsendii+virginianus&x=2&y=9.

NatureServe. 2014b. *Myotis grisescens*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed December 2014. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Myotis+grisescens&x=4&y=1.

NatureServe. 2014c. *Myotis septentrionalis*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Myotis+septentrionalis&x=8&y=9.

NatureServe. 2014d. *Charadrius melodus*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Charadrius+melodus&x=7&y=3.

NatureServe. 2014e. *Grus americana*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Grus+americana&x=15&y=10.

NatureServe. 2014f. *Sternula antillarum*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Sternula+antillarum&x=9&y=7.

NatureServe. 2014g. *Etheostoma chienense*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 30, 2015. http://explorer.natureserve.org/servlet/NatureServe?loadTemplate=tabular_report.wmt&paging=home&save=all&sourceTemplate=reviewMiddle.wmt.

NatureServe. 2014h. *Notropis albizonatus*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Notropis+albizonatus&x=2&y=12.

NatureServe. 2014i. *Phoxinus cumberlandensis*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Phoxinus+cumberlandensis&x=13&y=10.

NatureServe. 2014j. *Scaphirhynchus albus*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Scaphirhynchus+albus&x=8&y=10.

NatureServe. 2014k. *Scaphirhynchus platorynchus*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Scaphirhynchus+platorynchus&x=5&y=16.

NatureServe. 2014l. *Epioblasma obliquata obliquata*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Epioblasma+obliquata+obliquata&x=0&y=0.

NatureServe. 2014m. *Alasmidonta atropurpurea*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Alasmidonta+atropurpurea&x=5&y=14.

NatureServe. 2014n. *Cyprogenia stegaria*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Cyprogenia+stegaria&x=9&y=5.

NatureServe. 2014o. *Epioblasma torulosa rangiana*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Epioblasma+torulosa+rangiana&x=4&y=5.

NatureServe. 2014p. *Epioblasma triquetra*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Epioblasma+triquetra&x=0&y=0.

NatureServe. 2014q. *Plethobasus cooperianus*. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Updated March 2014; accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Plethobasus+cooperianus&x=4&y=4.

NatureServe. 2014r. *Pleurobema plenum* (Rough Pigtoe). NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Pleurobema+plenum&x=1&y=9.

NatureServe. 2014s. *Potamilus capax* (Green, 1832) Fat Pocketbook. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Potamilus+capax&x=12&y=8.

NatureServe. 2014t. *Quadrula cylindrica cylindrica* (Say, 1817) Rabbitsfoot. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Quadrula+cylindrica+cylindrica&x=3&y=9.

NatureServe. 2014u. *Quadrula fragosa* (Conrad, 1835) Winged Mapleleaf. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Access January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchName=Quadrula+fragosa.

NatureServe. 2014v. *Villosa trabalis* (Conrad, 1834). NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. Accessed January 2015.
http://explorer.natureserve.org/servlet/NatureServe?searchName=Villosa+trabalis

Neel, J.K. 1941. A Taxonomic study of *Quadrula quadrula* (Rafinesque). Occasional Papers of the Museum of Zoology, University of Michigan, 448(96): 1-8.

Neel, J. K. and W.R. Allen. 1964. The mussel fauna of the Upper Cumberland Basin before its impoundment. Malacologia, 1(3): 427-459.

Neves, R.J. 1991. Mollusks. Pages 251-320 in K. Terwilliger (ed.). Virginia's Endangered Species. Proceedings of a Symposium, Department of Game and Inland Fisheries. McDonald and Woodward Publishing Company, Blacksburg, Virginia. 672 pp.

Neves R.J. *(*1993*)* A state-of-the-unionids address. *In: Conservation and Management of Freshwater Mussels, Proceedings of a UMRC Symposium, 12–14. October, 1992, St Louis, MO (Eds K.W. Cummings, A.C. Buchanan & L.M. Koch), pp. 1–10. Upper Mississippi River Conservation Committee, Rock Island, IL, USA.*

Neves R.J., Bogan A.E., Williams J.D., Ahlstedt S.A., Hartfield P.W. *(*1997*)* Status of the aquatic mollusks in the southeastern United States: a downward spiral of diversity. *In: Aquatic Fauna in Peril: the Southeastern Perspective (Eds G.W. Benz & D.E. Collins), pp. 43–86. Special Publication 1, Southeast Aquatic Research Institute, 554 pp. Decatur, GA, U.S.A.*

Nichols, S.J., and D. Garling 2000. Food-web dynamics and trophic level interactions in a multispecies community of freshwater unionids. Canadian Journal of Zoology 78:871-882.

Niles, L. J., et al. 2007. Status of the red knot (*Calidris canutus rufa*) in the Western Hemishere. Report preparded for U.S. Fish and Wildlife Service, Ecological Services, Region 5, New Jersey Field Office, 927 North Main Street, Pleasantville, New Jersey 08232.

O'Bara C. J. 1990. Distribution and ecology of the blackside dace, *Phoxinus cumberlandensis* (Osteichthyes: Cyprinidae). Brimleyana 16:9-16.

Oesch, R.D. 1984. Missouri Naiades: a Guide to the Mussels of Missouri. Jefferson City, Missouri: Conservation Commision of the State of Missouri. 270 pp.

Oesch, R.D. 1995. Missouri Naiades. A Guide to the Mussels of Missouri. Second edition. Missouri Department of Conservation: Jefferson City, Missouri. viii + 271 pp.

Olson, R., J.R. Powell, A.R. Henderson, and P.L. Freeman. 2013. Effects of Lock and Dam Number Six on Aquatic Ecosystems in Mammoth Cave National Park. U.S. Geological Survey, Mammoth Cave, Ky. Accessed: December 30, 2014. http://pubs.usgs.gov/sir/2008/5023/18olson.htm

Orr, P.L., C.I. Wiramanden, M.D. Paine, W. Franklin and C. Fraser. 2012. Food chain model based on field data to predict westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) ovary selenium concentrations from water selenium concentrations in the Elk Valley, British Columbia. Environ. Toxicol. Chem. 31(3): 672-680.

Ortmann, A.E. 1918. The systematic position of two species of mussels from the Ozarks. Nautilus 32(1): 13-15.

Ortmann, A.E. 1919. Monograph of the naiades of Pennsylvania. Part III. Systematic account of the genera and species. Memoirs of the Carnegie Museum 8(1):1-385.

Page, L. M., P. A. Ceas, D. L. Swofford, and D. G. Buth. 1992 Evolutionary relationships within the *Etheostoma squamiceps* complex (Percidae; subgenus *Catonotus*) with descriptions of five new species, Copeia 1992:615-646.

Page, L. M., and B. M. Burr. 2011. Peterson field guide to freshwater fishes: North America north of Mexico. Second edition. Houghton Mifflin Harcourt, Boston, xix + 663 pp.

Palace VP, Spallholz JE, Holm J, Wautier K, Evans RE, Baron CL. 2004. Metabolism of selenomethionine by rainbow trout (*Oncorhynchus mykiss*) embryos can generate oxidative stress. *Ecotoxicol Environ Saf* 58:17-21.

Parmalee, P.W. 1967. The freshwater mussels of Illinois. Illinois State Museum, Popular Science Series 8:1-108.

Parmalee, P.W., W.E. Kippel, and A.E. Bogan. 1980. Notes on the prehistoric and present status of the naiad fauna of the middle Cumberland River, Smith County, Tennessee. The Nautilus, 94(3): 93-105.

Parmalee, P.W. and A.E. Bogan. 1998. The Freshwater Mussels of Tennessee. University of Tennessee Press: Knoxville, Tennessee. 328 pp.

Piller, K. R., and B. M. Burr. 1998. Distribution and population estimates of the federally endangered relict darter, *Etheostoma chienense,* Bayou du Chien, Kentucky. Journal of the Kentucky Academy of Science 59:64-75.

Piller, K. R., and B. M. Burr. 1999. Reproductive biology and spawning habitat supplementation of the relict darter, *Etheostoma chienense*, a federally endangered species. Environmental Biology of Fishers 55(1-2):145-155.

Poole, K. E., and J. A. Downing. 2004. Relationship of declining mussel biodiversity to stream-reach and watershed characteristics in an agricultural landscape. Journal of the North American Benthological Society 23 (1):114-125. 2004

Rakes, P.L., J.R. Shute, and P.W. Shute. 1999. Reproductive behavior, captive breeding, and restoration ecology of endangered fishes. *Environmental Biology of Fishes* 55:31–42.

Ramsey, J. S. 1986. Paleband shiner, *Notropis* sp. cf. *procne*, p. 6-7. *In*: R. H. Mount (ed.), Vertebrate animals in Alabama in need of special attention. Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama.

Rapp, T., D.A. Shuman, B.D.S. Graeb, S.R. Chipps, and E.J. Peters. 2011. Diet composition and feeding patterns of adult shovelnose sturgeon (*Scaphirhynchus platorynchus*) in the lower Platte River, Nebraska, USA. *Journal of Applied Ichthyology* 27:351–355.

Rasmussen, J. L. 2001. "A Compendium of Fishery Information on the Upper Mississippi River Third Edition 2001" *Scaphirhynchus platorynchus*.

Reddy, C. C. and E. J. Massaro. 1983. Biochemistry of selenium: an overview. Fund. Appl. Toxicol. 3:431-436.

Richter, A. R., et al. 1993. Modified cave entrances: thermal effect on body mass and resulting decline of endangered Indiana bats (MYOTIS SODALIS). Conservation Biology 7:407

Rodgers, S.O., B.T. Watson, and R. J. Neves. 2001. Life history and population biology of the endangered tan riffleshell (*Epioblasma florentina walkeri*) (Bivalvia: Unionidae). Journal of the North American Benthological Society 20:582-594.

Roley, S.S. 2012. The Influence of Floodplain Restoration on Stream Ecosystem Function in an Agricultural Landscape. Ph.D. diss., University of Notre Dame, Great Bend, IN. Accessed January 2015. http://etd.nd.edu/ETD-db/theses/available/etd-11292012 224803/unrestricted/RoleyS112012D.pdf

Sample, B. E., and R. C. Whitmore. 1993. Food habits of the endangered Virginia big-eared bat in West Virginia. J. Mammalogy 74:428-435.

Schrauzer GN. 2000. Selenomethionine: a review of its nutritional significance, metabolism and toxicity. *J Nutr* 130:1653-1656.

Schuster, G.A. 1988. Distribution of unionids (Mollusca: Unionidae) in Kentucky. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky, publication 2-437-R. 1099 pp.

Schweitzer, S.H., and D.M. Leslie Jr. 1996. Foraging patterns of the least tern (*sterna antillarum*) in north-central Oklahoma. *The Southwestern Naturalist* 41(3):307–314.

Sechler, D.R., Q.E. Phelps, S.J. Tripp, J.E. Garvey, D.P. Herzog, D.E. Ostendorf, J.W. Ridings, J.W. Crites, and R.A. Hrabik. 2012. Habitat for age-0 shovelnose sturgeon and pallid sturgeon in a large river: Interactions among abiotic factors, food, and energy intake. *North American Journal of Fisheries Management* 32:24–31.

Sickel, J. B. 1987. Preliminary survey for endangered freshwater mussels at Cumberland Island Towhead, confluence of the Cumberland and Ohio Rivers, Livingston County, Kentucky. Report prepared for Donan Engineering, Inc., Madisonville, Kentucky. 9 pp.

Sickel, J.B. and C.C. Chandler. 1996. Unionid fauna of the lower Cumberland River from Barkley Dam to the Ohio River, Kentucky (Mollusca: Bivalvia: Unionidae). Transactions of the Kentucky Academy of Science, 57(1): 33-46.

Silverman H., Nichols S.J., Cherry J.S., Archberger E., Lynn J.W., Dietz T.H. *(*1997*)* Clearance of laboratory-cultured bacteria by freshwater bivalves: differences between lentic and lotic unionids. *Canadian Journal of Zoology,* **75,** 1857–1866.

Silvis, A., A.B. Kniowski, S.D. Gehrt, and W.M. Ford. 2014. Roosting and foraging social structure of the endangered Indiana bat (myotis sodalis). *PLoS ONE* 9(5):e96937.

Simpson, C.T. 1899. The pearly fresh-water mussels of the United States; their habits, enemies, and diseases, with suggestions for their protection. Bulletin of the U.S. Fish Commission [Issued separately as U.S. Bureau of Fisheries Document 413] 18(1898):279-288.

Simpson, C.T. 1914. A Descriptive Catalogue of the Naiades or Pearly Fresh-water Mussels. Bryant Walker: Detroit, Michigan. 1540 pp.

Smith, P.W. 1971. Illinois streams: A classification based on their fishes and an analysis of factors responsible for disappearance of native species. Illinois Natural History Survey Biological Notes 76:1-14.

Snyder, N. and H. Snyder. 1969. A comparative study of mollusk predation by Limpkins, Everglade Kites, and Boat-tailed Grackles. Eighth Annual Report of the Cornell Laboratory of Ornithology 8:177-223.

Soule, M. E. 1980. Threshold for Survival: Maintaining Fitness and Evolutionary Potential. Pages 151-169 IN: M.E. Soule and B.A. Wilcox (eds.), Conservation Biology. Sinauer Assoc., Inc., Sunderland, MA.

Sparks, D. W., C. M. Ritzi, J. E. Duchamp, and J. O. Whitaker, Jr. 2005. Foraging habitat of the Indiana bat (*Myotis sodalis*) at an urban-rural interface. Journal of Mammalogy 86:713-718.

Stadtman TC. 1996. Selenocysteine. *Ann Rev Biochem* 65:83-100.

Stansbery, D. H. 1971. Rare and endangered freshwater mollusks in eastern United States. Pages 5-18 in S.E. Jorgensen, and R.W. Sharp. Proceedings of a symposium of rare and endangered mollusks (naiads) of the United States. U.S. Department of the Interior: Twin Cities, Minnesota. 79 pp.

Stansbery, D.H. 1976. Naiad mollusks. Pages 42-52 in H. Boschung (ed.). Endangered and threatened plants and animals of Alabama. Bulletin of the Alabama Museum of Natural History 2:1-92.

Stansbery, D.H., K. Borror, and K.E. Newman. 1982. Biological abstracts of selected species of Unionid mollusks recovered from Ohio. Unpublished. Prepared for the Ohio Heritage Foundation, Ohio Department of Natural Resources.Strayer, D. 1983. The effects of surface geology and stream size on freshwater mussel (Bivalvia, Unionidae) distribution in southeastern Michigan, U.S.A. Freshwater Biology 13:253-264.

Strayer, D.L., and A.R. Fetterman. 1999. Changes in the distribution of freshwater mussels (Unionidae) in the upper Susquehanna River basin, 1955–1965 to 1996–1997. *American Midland Naturalist* 142(2):328–339.

Strayer, D. L., K. A. Hattala, and A.W. Kahnle. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fish. Aquatic Science Vol. 61, 2004. 924 – 94

Strayer, D.L. 2008. *Freshwater Mussel Ecology - A Multifactor Approach to Distribution and Abundance.* University of California Press, Berkeley, CA.

Starnes, L. B., and W. C. Starnes. 1981. Biology of the blackside dace *Phoxinus cumberlandensis*. American Midland Naturalist 106:360-371.

Starnes, W. C., and L. B. Starnes. 1978. A new cyprinid of the genus *Phoxinus* endemic to the upper Cumberland River drainage. Copeia 1978:508-516.

Starnes, W.C., and L.B. Starnes. 1978b. Status report on a new and threatened species of *Phoxinus* from the upper Cumberland Drainage. Southeastern Fishes Council Proceedings. 2:2, 2pp.

Starnes, W. C., and D. A. Etnier. 1980. Fishes, p. B1-B134. *In*: D. C. Eager and R. M. Hatcher (eds.). Tennessee's rare wildlife, Volume I: the vertebrates. Tennessee Wildlife Resources Agency and Tennessee Heritage Program, Nashville, Tennessee.

Starnes, W.C. 1981. Listing package for the blackside dace (*Phoxinus cumberlandensis*). Report to the U.S. Department of Interior, Fish and Wildlife Service, 100 Otis Street, Room224, Asheville, NC. 41pp. plus Appendices A and B.

Starnes, W. C., and D. A. Etnier. 1986. Drainage evolution and fish biogeography of the Tennessee and Cumberland rivers drainage realm, p. 325-361. *In*: C. H. Hocutt and E. O. Wiley (eds.). The zoogeography of North American freshwater fishes. John Wiley and Sons, New York, New York.

Starnes, L. B., and A. E. Bogan. 1988. The Mussels (Mollusca:Bivalvia: Unionidae) of Tennessee. American Malacological Bulletin. 6(1):19-37.

Staton, S.K., J.L. Metcalfe-Smith, and E.L. West. 2000. Status of the northern riffleshell, *Epioblasma torulosa rangiana* (Bivalvia: Unionidae), in Ontario and Canada. The Canadian Field-Naturalist, 114: 224-235.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman and W.A. Brungs. 1985. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Life.

Stewart, R., M. Grosell, D. Buchwalter, N. Fisher, S. Luoma, T. Mathews, P. Orr, and W.-X. Wang. 2010. Bioaccumulation and trophic transfer of selenium. In: Ecological assessment of selenium in the aquatic environment. Chapman, P.M., W.J. Adams, M.L. Brooks, C.G. Delos, S.N. Luoma, W.A. Maher, H.M. Ohlendorf, T.S. Presser, and D.P. Shaw (Eds). SETAC Workshop on ecological assessment of selenium in the aquatic environment. CRC Press. Boca Raton, FL, New York, NY, London. 339 pp.

Stucker, J.H., D.A. Buhl, and M.H. Sherfy. 2012. Emergent sandbar construction for least terns on the Missouri River: Effects on forage fishes in shallow-water habitats. *River Research and Applications* 28:1254–1265.

Sunde, R. A. 1984. The biochemistry of selenoproteins. J. Am. Chem. Soc. 61:1891-1900

Szymanski, J. 1998. Leptodea leptodon (scaleshell mussel) rangewide status assessment. Report prepared for U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 16 pp. + app.

Taylor, R.W. and R.C. Hugart. 1981. The freshwater naiads of Elk River, West Virginia, with a comparison of earlier collections. The Nautilus, 95(1): 21-25.

Tennessee Valley Authority. 1976. Mussel fauna of the Cumberland River in Tennessee (September 1976). Tennessee Valley Authority, Division of Environmental Planning and Division of Forestry, Fisheries, and Wildlife Development, Muscle Shoals, Alabama, and Norris, Tennessee. 57 pp.

Thomas, D. W. 1995. Hibernating bats are sensitive to nontactile human disturbance. Journal of Mammalogy 76:940-946 Organisms and Their Uses. EPA 822-R85-100, Office of Research and Development, Washington, D.C.

Tuttle, M. D. 1976. Population ecology of the gray bat (*Myotis grisescens*): philopatry, timing, and patterns of movement, weight loss during migration, and seasonal adaptive strategies. University of Kansas Museum of Natural History Occasional Papers (54):1-38.

Tuttle, M. D. 1976. Population ecology of the gray bat (MYOTIS GRISESCENS): factors influencing growth and survival of newly volant young. Ecology 57:587-95.

Tuttle, M. D. 1977. Gating as a means of protecting cave dwelling bats. Pages 77-82 in T. Aley and D. Rhodes, editors. National cave management symposium proceedings.

Tuttle, M. D., and D. E. Stevenson. 1977. An analysis of migration as a mortality factor in the gray bat based on public recoveries of banded bats. Am. Midl. Nat. 97:235-40.

Tuttle, M. D. 1979. Status, causes of decline, and management of endangered gray bats. Journal of Wildlife Management 43:1-17.

Tuttle, M. D. 1979. Twilight for the gray bat. Nat. Parks Conserv. Mag. 53:12-15.

Tuttle, N.M., D.P. Benson, and D.W. Sparks. 2006. Diet of the *myotis sodalis* (Indiana bat) at an urban/rural interface. *Northeastern Naturalist* 13(3):435–442.

Twente, J. W. 1955. Some aspects of habitat selection and other behavior of cavern-dwelling bats. Ecology 36:706-32.

USEPA, Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses, 1985.

U.S. EPA. 1987. Ambient water quality criteria for selenium. EPA-440/5-87-006. National Technical Information Service.

USEPA (United States Environmental Protection Agency). 1998. Report of the peer consultation workshop on selenium aquatic toxicity and bioaccumulation. EPA-822-R-98-007. Office of Water, Washington, DC, USA.

USEPA. 2004. Draft Aquatic Life Water Quality Criteria for Selenium - 2004. EPA-822-D-04-001, Office of Water, Washington, D.C.

USEPA (U.S. Environmental Protection Agency). 2007a. *Appendix C: Status and Life History of the Pallid Sturgeon* (*Scaphirhynchus albus*). U.S. Environmental Protection Agency, Office of Pesticide Programs, Washington, DC.

USEPA. Office of Wetlands, Oceans and Watersheds Office of Research and Development. Washington, DC. February 28, 2013. National Rivers and Streams Assessment 2008–2009 A Collaborative Survey (DRAFT) EPA/841/D-13/001

U.S. Fish and Wildlife Service. 1979.69206 Federal Register / Vol. 44, No. 232 /Friday, November 30, 1979 50 CFR Part 17 Endangered and Threatened Wildlife and Plants; Listing of Virginia and Ozark Big-Eared Bats and Endangered Species and Critical Habitat Determination.

U.S. Fish and Wildlife Service. 1980. Selected vertebrate endangered species of the seacoast of the United States--the whooping crane. FWS/OBS-80/01.3, Slidell.

U.S. Fish and Wildlife Service (USFWS). 1984. Recovery plan for the Dromedary Pearly Mussel; *Dromus dromas*, *Dromus dromas* form *caperatus*. U.S. Fish and Wildlife Service, Region 4, Atlanta, Georgia.

U.S. Fish and Wildlife Service (USFWS) (Ahlstedt, S.A.) 1984. Recovery plan for the white warty-back pearly mussel (*Plethobasus cicatricosus*) (Say 1829). U.S. Fish and Wildlife Service, Region 4, Atlanta, Georgia. 43 pp.

U.S. Fish and Wildlife Service (USFWS) (Ahlstedt, S.). 1984. Recovery plan for the rough pigtoe pearly mussel; *Pleurobema plenum* (Lea, 1840), U.S. Fish and Wildlife Service, Region 4, Atlanta, Georgia. 51 pp.

U.S. Fish and Wildlife Service (USFWS) (Ahlstedt, S.A.) 1984. Recovery plan for the orange-footed pearly mussel (*Plethobasus cooperianus*) (Lea 1834). U.S. Fish and Wildlife Service, Region 4, Atlanta, Georgia. 44 pp.

U. S. Fish and Wildlife Service (USFWS). 1984. Recovery plan for the Cumberland Bean Pearly Mussel *Villosa trabalis* (Conrad, 1834), U.S. Fish and Wildlife Region 4, Atlanta, Georgia. 58 pp.

U.S. Fish and Wildlife Service (USFWS). 1985e. Recovery plan for the pink mucket pearly mussel; *Lampsilis orbiculata* (Hildreth, 1828). U.S. Fish and Wildlife Service, Region 4, Atlanta, Georgia. 47 pp.

U.S. Fish and Wildlife Service. 1987. Determination of threatened species status for the blackside dace. Federal Register 52:22580-5.

U.S. Fish and Wildlife Service. 1988. Blackside Dace Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 23pp.

U.S. Fish and Wildlife Service (USFWS). 1988. Determination of endangered species status for the little-wing pearly mussel. Federal Register, 53(219): 45861-45865.

U.S. Fish and Wildlife. 1988. Kentucky Cave Shrimp (Palaemonias ganteri) Recovery Plan U.S. Fish and Wildlife Service, Atlanta, Georgia.

U.S. Fish and Wildlife Service (USFWS). 1989m. A Recovery Plan for the fat pocketbook pearly mussel *Potamilus capax* (Green, 1832). U.S. Fish and Wildlife Service, Atlanta, Georgia. 22 pp.

U.S. Fish and Wildlife Service (USFWS). 1989n. Little-wing pearly mussel recovery plan. U.S. Fish and Wildlife Service: Atlanta, Georgia. 29 pp.

U.S. Fish and Wildlife Service. September, 1990. Recovery Plan for the Interior Population of the Least Tern (*Sterna antillarum*). Sidle and Harrison

U.S. Fish and Wildlife Service. 1990. Endangered and Threatened Wildlife and Plants; Designation of the Freshwater Mussel, the Fanshell as an Endangered Species. Federal Register 55(120): 25591-25596.

U.S. Fish and Wildlife Service. 1990. Endangered and threatened species recovery program: report to Congress. 406 pp.

U.S. Fish and Wildlife Service (USFWS). 1990d. Purple cat's paw pearly mussel recovery plan. U.S. Fish and Wildlife Service: Atlanta, Georgia. 26 pp.

U.S. Fish and Wildlife Service (USFWS). 1990e. White cat's paw pearly mussel recovery plan. U.S. Fish and Wildlife Service: Twin Cities, Minnesota. 42 pp.

U.S. Fish and Wildlife Service (USFWS). 1990h. Cracking pearlymussel (*Hemistena* (= *Lastena*) *lata*) recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia. 25 pp.

U.S. Fish and Wildlife Service. 1991. Recovery Plan for Fanshell (*Cyprogenia stegaria (=c. Irrorata)*). Region 4. Atlanta, GA. 37 pp.

U.S. Fish and Wildlife Service (USFWS). 1991. Ring pink mussel recovery plan. U.S. Fish and Wildlife Service: Atlanta, Georgia. 24 pp.

U.S. Fish and Wildlife Service. 1992. Proposal to list the relict and bluemask (jewel) darters as endangered species. Federal Register 57(239):58774-58779, 11 December 1992.

U.S. Fish and Wildlife Service (USFWS). 1992. Recovery plan for purple cat's paw pearlymussel (*Epioblasma* (=*Dysnomia*) *obliquata obliquata* (=*Epioblasma sulcata sulcata*)). Prepared by R.G. Biggins, U.S. Fish and Wildlife Service: Atlanta, Georgia. 26 pp.

U.S. Fish and Wildlife Service. 1993 Endangered and Threatened Wildlife and Plants; determination of the palezone shiner (*Notropis* sp., cf. *procne)* to be an endangered species. *Federal Register* 58(79):25758-25763.

U.S. Fish Wildlife Service. 1993. Recovery Plan for the Pallid Sturgeon, *Scaphirhynchus albus*. USFWS Region 6, Denver, CO. 55 pp.

U.S. Fish and Wildlife Service (USFWS). 1993. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Northern Riffleshell Mussel (*Epioblasma torulosa rangiana*) and the Clubshell Mussel (*Pleurobema clava*) (Final Rule). Federal Register, 58(13): 5638-5642.

U.S. Fish and Wildlife Service. 1993. Determination of endangered status for the relict darter and bluemask (jewel) darter. Federal Register 58(246):68480-6.

U.S. Fish and Wildlife Service. 1993. Determination of endangered status for the duskytail darter, paleozone shiner and pygmy madtom. Federal Register (58(79):25758-25763.

U.S. Fish and Wildlife Service (USFWS). 1994. Clubshell (Pleurobema clava) and northern riffleshell (Epioblasma torulosa rangiana) recovery plan. U.S. Fish and Wildlife Service, Hadley, Massachusetts. 58 pp.

U.S. Fish and Wildlife Service. 1994. Relict darter technical/agency draft recovery plan. Atlanta, Georgia. 44 pp.

USFWS. 1995. Endangered and Threatened Species of the Southeastern United States (The Red Book). USFWS Region 4.

U.S. Fish and Wildlife Service (USFWS). 1997. Determination of Endangered Status for the Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot. Final rule. Federal Register, 62(7): 1647-1658.

U.S. Fish and Wildlife Service. 1997. Recovery Plan for Palezone Shiner) *Notropis albizonatus).* Atlanta, GA. 27 pp.

U.S. Fish and Wildlife Service (USFWS). 1997. Winged mapleleaf mussel (Quadrula fragosa) recovery plan. U.S. Fish and Wildlife Service, Ft. Snelling, Minnesota. 69 pp. + app.

USFWS (U.S. Fish and Wildlife Service). 1997a. Pink Mucket (*Lampsilis orbiculata*) Endangered Species Fact Sheet. Accessed January 2015. http://www.fws.gov/midwest/endangered/clams/pinkm_fc.html.

USFWS (U.S. Fish and Wildlife Service). 1997b. Cracking Pearlymussel (*Hemistena lata*) Endangered Species Fact Sheet. Accessed January 2015. http://www.fws.gov/midwest/endangered/clams/crack_fc.html.

USFWS (U.S. Fish and Wildlife Service). 1997c. Winged Mapleleaf Mussel (*Quadrula fragosa*) Recovery Plan. U.S. Fish and Wildlife Service Region 3, Ft. Snelling, MN. Accessed January 2015. http://ecos.fws.gov/docs/recovery_plan/970625.pdf.

USFWS (U.S. Fish and Wildlife Service). 1998. Pallid Sturgeon (*Scaphirhynchus albus*) Endangered Species Fact Sheet. Accessed January 2015. http://www.fws.gov/midwest/Endangered/fishes/palld_fc.html.

U.S. Fish and Wildlife Service. 1999. Status review: Cumberland johnny darter (*Etheostoma susanae*). USFWS, Asheville, North Carolina. 5 pp,

U.S. Fish and Wildlife Service. 1999. Agency draft Indiana Bat (*Myotis sodalis*) revised recovery plan. U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 53 pp.

U.S. Fish and Wildlife Service (USFWS). 1999. Candidate and listing priority assignment forms.

U.S. Fish and Wildlife Service. 2001. Candidate and listing priority assignment form- *Ptychobranchus subtentum*. U.S. Fish and Wildlife Service, Ashville, North Carolina. 15 pp.

U.S. Fish and Wildlife Service. 2001. *Etheostoma nigrum susanae* candidate and listing priority assignment form. USFWS, Asheville, North Carolina.

USFWS (U.S. Fish and Wildlife Service). 2002. Status Assessment Report for the Sheepnose, *Plethobasus cyphyus*, occurring in the Mississippi River system (U.S Fish and Wildlife Service Regions 3, 4, and 5). U.S. Fish and Wildlife Service, Ohio River Valley Ecosystem Team. Accessed January 2015. http://www.fws.gov/midwest/Endangered/clams/pdf/sheepnose-sa.pdf.

U.S. Fish and Wildlife Service. 2003. Candidate assessment and listing priority assignment form- *Lexingtonia dolabelloides*. U.S. Fish and Wildlife

U.S. Fish and Wildlife Service. 2003. Species Account, Fanshell (*Cyprogenia Stegaria*). Available http://endangered.fws.gov/i/f/saf14.html. (Accessed: December 4, 2003).

U.S. Fish and Wildlife Service (USFWS). 2003. Endangered and Threatened Wildlife and plants; proposed designation of critical habitat for five threatened mussels in the Tennessee and Cumberland River basins; proposed rule. Federal Register, 68(106): 33234-33282

USFWS (U.S. Fish and Wildlife Service). 2003. *Agency Draft Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot*.Atlanta, GA

U.S. Fish and Wildlife Service (USFWS). 2004. Endangered and Threatened Wildlife and plants; designation of critical habitat for five endangered mussels in the Tennessee and Cumberland River basins; final rule. Federal Register, 69(168): 53135-53180.

U.S. Fish and Wildlife Service (USFWS). 2004. Recovery plan for Cumberland elktoe, oyster mussel, Cumberlandian combshell, purple bean, and rough rabbitsfoot. U.S. Fish and Wildlife Service, Atlanta, Georgia. 168 pp.

U.S. Fish and Wildlife Service. 2004. Scaleshell mussel draft recovery plan (Leptodea leptodon). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 90 pp.

U.S. Fish and Wildlife Service (USFWS). 2006. Endangered and threatened wildlife and plants; establishment of nonessential experimental population status for 15 freshwater mussels, 1 freshwater snail, and 5 fishes in the lower French Broad River and in the lower Holston River, Tennessee; Proposed Rule. Federal Register, 71(113): 34195-34230.

USFWS (U.S. Fish and Wildlife Service). 2006. *Threatened and Endangered Species Fact Sheet: Indiana Bat (*Myotis sodalis*)*. Department of the Interior. Updated November 2014; accessed January 2015. http://www.fws.gov/midwest/endangered/mammals/inba/pdf/inbafctsht.pdf.

U.S. Fish and Wildlife. 2007. Kentucky Cave Shrimp (Palaemonias ganteri) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife, Frankfurt, KY.

USFWS (U.S. Fish and Wildlife Service). 2007a. *Indiana Bat (*Myotis sodalis*) Draft Recovery Plan: First Revision*. U.S. Fish and Wildlife Service, Fort Snelling, MN.

USFWS (U.S. Fish and Wildlife Service). 2007b. *Relict darter (*Etheostoma chienense*). 5-Year Review: Summary and Evaluation*. Southeast Region, Kentucky Ecological Services Field Office, Frankfort, KY.

USFWS (U.S. Fish and Wildlife Service). 2007c. *Kentucky Cave Shrimp (*Palaemonias ganteri*) 5-Year Review: Summary and Evaluation*. U.S. Fish and Wildlife, Frankfurt, KY.

U.S. Fish and Wildlife. 2008. Virginia Big-Eared Bat (Corynorhinus townsendii verginianus) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife, Elkins, West Virginia

U.S. Fish and Wildlife Service Midwest Region – Region 3 Indiana Bat 5-Year Review: summary and Evaluation September 2009.

U.S. Fish and Wildlife Service (USFWS). 2010. Species assessment and listing priority assignment form: *Lexingtonia dolabelloides.* U.S. Fish and Wildlife Service, Endangered Species Program, Cookeville, Tennessee. 19 pp.

U.S. Fish and Wildlife Service (USFWS). 2010. Cumberland bean (*Villosa trabalis*) 5-year review: Summary and evaluation. U.S. Fish and Wildlife Service, Frankfort, Kentucky. 14 pp.

U.S. Fish and Wildlife Service. 1 September 2010. Endangered and Threatened Wildlife and Plants; Threatened Status for Shovelnose Sturgeon Under the Similarity of Appearance Provisions of the Endangered Species Act 50 FR Part 17. 53598

U.S. Fish and Wildlife Service. 29 June 2011. 90-day finding on a petition to list the eastern small-footed bat and the northern long-eared bat as threatened or endangered. Federal Register 76(125):38095-38106.

U.S. Fish and Wildlife Service. August 2011. Birdwing pearlymussel (*Conradilla caelata [=Lemiox rimosus]*), Dromedary pearlymussel (*Dromus dromas*), Cracking pearlymussel (*Hemistena lata*) 5-Year Review: Summary and Evaluation, Cookeville Ecological Services Field Office, Cookeville, Tennessee.

U.S. Fish and Wildlife Service. 9 August 2011. Endangered status for the Cumberland darter, rush darter, yellowcheek darter, chucky madtom, and laurel dace. Federal Register 76(153):48722-48741.

U.S. Fish and Wildlife Service. 12 October 2011. Proposed designation of critical habitat for the Cumberland darter, rush darter, yellowcheek darter, chucky madtom, and laurel dace. Federal Register 76(197):63360-63418.

U.S. Fish and Wildlife Service. August 2011. Birdwing pearly mussel, Dromedary pearlymussel, Crackling pearly mussel Five Year Review. Cookeville Ecological Services Field Office.

USFWS (U.S. Fish and Wildlife Service) 2012a. Sheepnose (a freshwater mussel) *Pethobasus cyphyus*. USFWS Endangered Species Midwest Region. Accessed January 2015. http://www.fws.gov/midwest/Endangered/clams/sheepnose/pdf/SheepnoseFactSheetMarch2012.pdf.

USFWS (U.S. Fish and Wildlife Service). 2012b. Littlewing Pearlymussel (*Pegias fabula*). U.S. Fish and Wildlife Service, Raleigh Ecological Services Field Office. Updated October 2011; accessed January 2015. http://www.fws.gov/raleigh/species/es_littlewing_pearlymussel.html.

USFWS (U.S. Fish and Wildlife Service). 2012c. *Snuffbox (freshwater mussel)* Epioblasma triquetra *Endangered Species Fact Sheet*.

USFWS (U.S. Fish and Wildlife Service). 2013a. *Red knot* Calidris canutus rufa *Fact Sheet*. U.S. Fish and Wildlife Service. Accessed January 2015.
http://www.fws.gov/northeast/redknot/pdf/Redknot_BWfactsheet092013.pdf.

USFWS (U.S. Fish and Wildlife Service). 2013b. *Interior Least Tern.* Sterna antillarum athallasos. *5-Year Review: Summary and Evaluation*. Southeast Region, Mississippi Field Office, Jackson, MS.

USFWS (U.S. Fish and Wildlife Service). 2013c. *Palezone Shiner* (Notropis albizonatus). *5-Year Review: Summary and Evaluation*. Southeast Region, Kentucky Ecological Services Field Office, Frankfort, KY.

USFWS (U.S. Fish and Wildlife Service). 2014a. *Letter to EPA: Summary of federally listed and proposed species and areas of designated critical habitat for consideration in Kentucky water quality standards biological evaluation.* U.S. Fish and Wildlife Service.

USFWS (U.S. Fish and Wildlife Service). 2014b. *Revised Recovery Plan for the Pallid Sturgeon* (Scaphirhynchus albus). Prepared for Mountain-Prairie Region, U.S. Fish and Wildlife Service by Pallid Sturgeon Recovery Coordinator, U.S. Fish and Wildlife Service Montana Fish and Wildlife Conservation Office, Billings, MT.

USFWS (U.S. Fish and Wildlife Service). 2014c. *Endangered Species: Ring Pink (*Obovaria retusa*) Fact Sheet*. Accessed December 2014.
http://www.fws.gov/midwest/Endangered/clams/ringp_fc.html.

USFS (U.S. Forest Service). 2006. *Bankhead National Forest Biological Evaluation of Proposed Salvage of Forestland Damaged by Hurricane Rita—2006,* Winston County, Alabama. Accessed January 2015. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5157322.pdf.

USGS. 2011. http://www.coloradoriverrecovery.org/documents-publications/work-plan-documents/arpts/2011/hab/Contaminants.pdf

USGS (U.S. Geological Survey). 2013. *Hydraulic Fracturing Fluids Likely Harmed Threatened Kentucky Fish Species*. News release August 2013. Accessed January 2015. http://www.usgs.gov/newsroom/article.asp?ID=3677.

Van der Hoeven N. 1997. How to measure no effect. Part 1: Towards a new measure of chronic toxicity? Envirometrics 8, 241-248.

Vannote, R.L. and G.W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proceedings of the National Academy of Sciences, 79: 4103-4107.

van Zyll de Jong, C. G. 1985. Handbook of Canadian Mammals, Volume 2. Bats. National Museums of Canada, Ottawa, Ontario, Canada. 212 pp.

Walls, E. A., J. Berkson, and S. A. Smith. 2002. The horseshoe crab, *Limulus polyphemus*: 200 million years of existence, 100 years of study. Reviews in Fisheries Science 10:39-73.

Wanner, G.A. and D.A. Shuman. 2007. Food habits of juvenile pallid sturgeon and adult shovelnose sturgeon in the Missouri River downstream of Fort Randall Dam, South Dakota. *Journal of Freshwater Ecology* 22(1):81–92.

Warne M. and Rick van Dam. 2008. NOEC and LOEC Data Should No Longer Be Generated or Used. Australasian Journal of Ecotoxicology. Vol. 14, pp 1-5.

Warren, M. L., Jr., B. M. Burr, and C. A. Taylor. 1994. The relict darter, *Etheostoma chienense (*Percidae): status review of a Kentucky endemic. Transactions of the Kentucky Academy of Science 55(1-2):20-27.

Warren, M. L., Jr., B. M. Burr, and J. M. Grady. 1994. *Notropis albizonatus*, a new cyprinid fish endemic to the Tennessee and Cumberland River drainages, with a phylogeny of the *Notropis procne* species group, Copeia 1994:868-86.

Warren, M. L., Jr., and B. M. Burr, 1998. Threatened fishes of the world: *Notropis albizonatus* Warren, Burr & Grady, 1994 (Cyprinidae). Environmental Biology of Fishes 51:128.

Waters, T. F. 1995. Sediment in streams: sources, biological effects and control. American Fisheries Society Monograph 7. Bethesda, Maryland. 251 pp.

Watters, G.T. 1990. 1990 Survey of the unionids of the Big Darby Creek system. Final Report to The Nature Conservancy. 229 pp.

Watters, G.T. 1992. Unionids, fishes, and the species-area curve. Journal of Biography 19:481-490.

Watters, G.T. 1994. *Clubshell (*Pleurobema clava*) and Northern Riffleshell (*Epioblasma tondosa rangiana*) Recovery Plan*. Prepared for U.S. Fish and Wildlife Service Region 5 by Ohio Department of Natural Resources, Columbus, OH. Accessed January 2015. http://ecos.fws.gov/docs/recovery_plan/940921.pdf.

Watters, G. T. 2000. Freshwater mussels and water quality: A review of the effects of hydrologic and instream habitat alterations. Pages 261-274 *in* P. D. Johnson and R. S. Butler, editors. Proceedings of the First Freshwater Mussel Conservation Society Symposium, 1999. The Ohio State University, Columbus, OH.

Watters, G.T., M.A. Hoggarth, and D.H. Stansbery. 2009. The Freshwater Mussels of Ohio. Ohio State University Press: Columbus, Ohio. 421 pp.

Watters, G.T. and C.J.M. Flaute. 2010. Dams, zebras, and settlements: The historical loss of freshwater mussels in the Ohio River mainstem. American Malacological Bulletin 28:1-12.

Welsh, S. A., R. M. Wood, and K. R. Sheehan. 2009. Threatened fishes of the world: *Crystallaria cincotta*

Welsh, S.A., D.M. Smith, and N.D. Taylor. 2013. Microhabitat use of the diamond darter. *Ecology of Freshwater Fish* 22:587–595.

Whitaker, J. O. Jr. 1972. Food habits of bats from Indiana. Can. J. Zoology. 50:877-83.

Wildhaber, M.L., A.J. DeLonay, D.M. Papoulias, D.L. Galat, R.B. Jackson, D.G. Simpkins, P.J. Braaten, C.E. Korschgen, and M.J. Mac. 2011. Identifying structural elements needed for development of a predictive life-history model for pallid and shovelnose sturgeons. *Journal of Applied Ichthyology* 27:462–469.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries **18**:6-22.

Winders, K.R., J.E. Dattilo, T.R. Huffmon, and V.H. Travichek. 2014. Seasonal diet composition of juvenile and adult pallid sturgeon, *Scaphirhynchus albus* (Forbes & Richardson, 1905), in the channelized lower Missouri River. *Journal of Applied Ichthyology* 30:1133–1140.

Yeager M.M., Cherry D.S., Neves R.J. (1994) Feeding and burrowing behaviors of juvenile rainbow mussels *Villosa iris* (Bivalvia: Unionidae). *Journal of the North American Benthological Society,* **13,**217–222.

Yuan T, Weljie AM, Vogel HJ. 1998. Tryptophan fluorescence quenching by methionine and selenomethionine residues of calmodulin: orientation of peptide and protein binding. Biochemistry 37:3187-3195.

Zanatta, D.T. and R.W. Murphy. 2007. Range-wide population genetic analysis of the endangered northern riffleshell mussel, *Epioblasma torulosa rangiana* (Bivalvia: Unionoida). *Conservation Genetics* 8:1393-1404.

Zanatta, D.T., and R.W. Murphy. 2008. The phylogeographical and management implications of genetic population structure in the imperiled snuffbox mussel, *Epioblasma triquetra* (Bivalvia : Unionidae). *Biological Journal of the Linnean Society*, 93:371–384.